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Scientific and Social Research

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Application Analysis of Quality Control Management in Blood Component Preparation at Blood Stations

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Abstract: Objective: To analyze the application effect of quality control management in blood component preparation at blood stations. Methods: A total of 1,984 blood samples prepared at the blood station from January 2024 to March 2025 were selected and divided into a control group (991 samples) and an experimental group (993 samples). The control group implemented routine preparation management, while the experimental group implemented full-process quality control management on this basis. The qualification rate of blood components, rejection rate, incident rate at key control points, and work quality were compared between the two groups. Results: The qualification rate of blood components in the experimental group was higher than that in the control group, and the rejection rate was lower than that in the control group ($P < 0.05$). The incident rate of abnormalities at each control point in the experimental group was significantly lower than that in the control group, and the disposal time in the experimental group was 9.35 ± 2.84 minutes, significantly shorter than that in the control group (23.41 ± 4.62 minutes) ($P < 0.05$). The experimental group scored significantly higher than the control group in terms of work quality ($P < 0.05$). Conclusion: Full-process quality control management can effectively improve the standardization and qualification rate of blood component preparation, contributing to the systematic and refined development of quality management at blood stations.

Keywords: Blood station; Blood component preparation; Quality control management; Full-process management

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1. Introduction

Blood stations are non-profit public health and medical institutions established by the state, responsible for collecting, testing, preparing, and supplying blood, with the collected blood primarily used for the continuous supply of clinical blood^[1]. Since the quality of blood used clinically directly relates to the transfusion safety and treatment outcomes of patients, strict quality control management of blood quality is required in the workflow of blood stations^[2]. Typically, after collecting blood, blood stations prepare blood components, a process that mainly involves physically separating the collected whole blood into various types of component blood for

targeted clinical use^[3]. To enhance the quality of blood component preparation at blood stations, it is necessary to implement comprehensive quality control management measures to ensure the safety of the blood supply from blood donation institutions^[4]. Therefore, this study will compare the changes in the qualification rate, discard rate, critical control point incident rate, and work quality scores of blood components under two management models, thereby providing a basis for the standardization, refinement, and continuous improvement of quality management in blood component preparation at blood stations.

2. Materials and methods

2.1. General information

A total of 1,984 blood component samples prepared and subjected to quality testing at a central blood station from January 2024 to March 2025 were included in the study. These samples were randomly divided into a control group and an experimental group using a random number table method, with 991 samples in the control group and 993 samples in the experimental group. In the control group, there were 991 blood component samples; among the blood donors, there were 556 males and 435 females; the age range was 18 to 54 years, with an average age of 31.62 ± 7.15 years; there were 617 first-time donors and 374 repeat donors; the average single donation volume was 392.46 ± 48.73 mL; the pre-donation hemoglobin level was 146.27 ± 11.63 g/L, systolic blood pressure was 117.85 ± 9.18 mmHg, and diastolic blood pressure was 74.33 ± 7.26 mmHg. In the experimental group, there were 993 blood component samples; among the blood donors, there were 552 males and 441 females; the age range was 18 to 55 years, with an average age of 31.48 ± 7.22 years; there were 610 first-time donors and 383 repeat donors; the average single donation volume was 393.21 ± 49.15 mL; the pre-donation hemoglobin level was 145.96 ± 11.72 g/L, systolic blood pressure was 118.02 ± 9.07 mmHg, and diastolic blood pressure was 74.52 ± 7.11 mmHg. There were no statistically significant differences in gender ratio, age distribution, or donation volume between the two groups of blood donors and prepared samples ($P > 0.05$). The study was approved by the ethics committee of the central blood station.

2.2. Inclusion and exclusion criteria

Inclusion criteria: (1) Blood donors met the physical and laboratory examination criteria outlined in the “Health Examination Requirements for Blood Donors”^[5]; (2) Aged between 18 and 55 years, with a body weight of ≥ 50 kg for males and ≥ 45 kg for females, and a hemoglobin concentration of ≥ 120 g/L; (3) Complete collection and component preparation process; (4) Blood donors provided informed consent for their samples to be used in this study.

Exclusion criteria: (1) Positive results in any of the serological tests (HBsAg, anti-HCV, anti-HIV, Treponema pallidum antibody) for blood donors; (2) Hemolysis, lipemic blood, or other conditions occurring during blood collection or preparation; (3) Incomplete sample test results or missing data records; (4) Other abnormal conditions that affect blood quality assessment.

2.3. Methods

The control group adopted a conventional management model during the blood component preparation process. The preparation process was divided into stages such as blood collection, packaging, centrifugation, separation, rapid freezing, and storage, with each position carrying out corresponding work tasks according to established operational standards. After blood reception, the receiving personnel verified the donor number, label, and volume,

and registered the blood into inventory after confirming that there was no damage, clotting, or hemolysis in appearance. Subsequently, preliminary stratification of whole blood was completed through conventional single-stage centrifugation. During the separation process, the operator segmented the plasma, red blood cell, and platelet layers, and immediately sealed and labeled them after separation. If any broken bags, poor sealing, or abnormal blood appearance were found during the preparation process, they were manually removed by the operator and reported to the quality inspector for registration. Plasma rapid freezing was completed within 6 hours after blood collection, with the rapid freezing temperature set at -30°C . After the finished blood products were packaged, they were stored in dedicated low-temperature refrigerators according to component types, and the temperature was recorded twice daily, in the morning and evening.

The experimental group implemented total process quality control management on the basis of conventional preparation. All personnel on duty were required to pass pre-job theoretical and practical assessments, and their operational error rates were assessed monthly. Before each shift, the quality control personnel verified the status of the instruments and environmental parameters, and filled out the equipment operation logs simultaneously. After blood collection, the information is double-checked, and an appearance inspection is conducted by two individuals to verify whether the blood bag seal, tubing, and labels are intact and clearly visible. Blood separation is completed within 4 hours of collection using a two-stage centrifugation method (initial centrifugation at 2000 r/min for 10 minutes, followed by secondary centrifugation at 3800 r/min for 10 minutes), and the blood is immediately transferred to the separation station after centrifugation. During the separation process, each bag of blood is weighed individually, with a balance tolerance of no more than ± 2 g. After plasma separation, the bag is sealed immediately, and the blood cell layer is processed through a leukocyte filtration device. Before thermo-sealing, the voltage and temperature of the sealing machine are checked. After thermo-sealing the catheter connectors, the operator reviews each one individually and records the serial numbers. Plasma is flash-frozen by distinguishing thickness according to specifications and placed flat on freezing plates. The start and end times of all operational steps, operator signatures, equipment serial numbers, and batch numbers are simultaneously recorded in the preparation quality control record form. Temperature and humidity are checked twice daily, and airborne microbial monitoring is conducted weekly. The surfaces of workstations and equipment are wiped and disinfected at least once daily. Consumables are received by the quality control personnel according to batch numbers, with checks for production dates, expiration dates, and packaging integrity. Any remaining consumables after use are sealed and stored separately. After each batch preparation, quality inspectors independently sample and test the suspended red blood cells, plasma, and platelet samples for quality. The tests include physical and chemical indicators, plasma clarity, platelet recovery rate, and bacteriological results, with all test items passing considered as qualified. The pass rate = (number of qualified products \div total number of tested products) \times 100%. Discarded samples refer to those that cannot be placed into inventory due to issues occurring during collection, centrifugation, separation, thermo-sealing, flash-freezing, storage, or testing.

2.4. Observation indicators

2.4.1. The qualification rate and rejection rate of blood component preparation

Quality inspections are conducted on prepared suspended red blood cells, plasma, and platelet samples. The inspections encompass various physicochemical indicators of the products, plasma clarity, platelet recovery rate, and bacteriological results. Samples that pass all inspection items are deemed qualified.

Pass rate = Number of qualified products ÷ Total number of inspected products × 100%.

Discarded samples refer to those that cannot be placed into inventory due to issues occurring during collection, centrifugation, separation, thermo-sealing, flash-freezing, storage, or testing.

Scrap rate = Number of scrapped samples ÷ Total number of samples entering the preparation process × 100%.

2.4.2. Event rate and handling time for key control points

Monitoring is conducted at six nodes: blood reception, centrifugation, component separation, catheter heat sealing, rapid freezing, and storage/transportation. Abnormal events at each node are recorded, including inconsistent information, unbalanced centrifugation, poor layering, sealing defects, failure to meet the target temperature at the center during rapid freezing, and temperature deviations during storage and transportation.

Event rate = Number of abnormal events ÷ Total number of operations at the node × 100%

Handling time refers to the duration (in minutes) from the discovery of an abnormal event to its correction or completion of handling.

2.4.3. Work quality

The quality of work is assessed using a self-developed quality evaluation scale for blood component preparation positions. The scale consists of 12 indicators across four dimensions: blood source collection management, preparation operation standards, equipment maintenance, and material and storage/transportation management, with a total score of 100 points. Scoring is based on a 5-level scale (20, 40, 60, 80, 100 points), and the average score is taken as the total score. The Cronbach's α of the scale is 0.92.

2.5. Statistical analysis

Data are imported into statistical software (SPSS version 24.0) for analysis. Measurement data are verified for distribution characteristics using the Shapiro-Wilk test. Data conforming to a normal distribution are expressed as mean \pm standard deviation (Mean \pm SD), and comparisons between two groups are made using the independent samples t-test. Data not conforming to a normal distribution are expressed as median (interquartile range), and comparisons between groups are made using the Mann-Whitney U test. Count data are expressed as frequency and composition ratio "[n/(%)]", and comparisons between groups are made using the χ^2 test. When the theoretical frequency is <5 , Fisher's exact probability method is used instead. All tests are two-sided, and a P -value <0.05 is considered statistically significant.

3. Results

3.1. Comparison of blood component preparation quality between two groups

The qualification rate of blood component preparation in the experimental group was significantly higher than that in the control group, while the rejection rate was significantly lower than that in the control group ($P < 0.05$) (Table 1)

Table 1. Comparison of blood component preparation quality between the two groups [%, Case (n)]

Group	Samples (n)	Qualified (n)	Qualified Rate (%)	Rejected (n)	Rejection Rate (%)
Control Group	991	904	91.22 (904/991)	91	9.18 (91/991)
Experimental Group	993	985	99.19 (985/993)	8	0.81 (8/993)
χ^2 -value		69.166			73.417
<i>P</i> -value		<0.001			<0.001

Note: The qualification rate was calculated based on the products that completed testing, while the rejection rate was calculated based on the samples that entered the preparation process

3.2. Comparison of event rates and response times at key control points between the two groups

The experimental group had lower abnormal event rates at six key nodes, namely blood reception, centrifugation, component separation, catheter heat sealing, rapid freezing, and storage/transportation, compared to the control group, and the response time was significantly shortened ($P < 0.05$) (Table 2).

Table 2. Comparison of event rates and response times at key control points between the two groups

Group	Information Mismatch n (%)	Centrifugal Imbalance n (%)	Poor Stratification n (%)	Sealing Defect n (%)	Inadequate Core Freezing Temp. n (%)	Storage/Transport Temp. Excursion n (%)	Processing Time (min, \pm s)
Control Group (n=991)	12/991 (1.21)	18/991 (1.82)	11/991 (1.11)	13/991 (1.31)	9/991 (0.91)	8/991 (0.81)	23.41 \pm 4.62
Experimental Group (n=993)	2/993 (0.20)	1/993 (0.10)	3/993 (0.30)	1/993 (0.10)	2/993 (0.20)	1/993 (0.10)	9.35 \pm 2.84
T/χ^2	7.214	15.392	4.620	10.383	4.494	5.483	81.676
<i>P</i> -value	0.007	<0.001	0.032	0.001	0.034	0.019	<0.001

3.3. Comparison of work quality scores between the two groups

The experimental group had significantly higher scores in all dimensions and overall scores compared to the control group ($P < 0.05$) (Table 3).

Table 3. Comparison of work quality scores between the two groups (points, mean \pm SD)

Group	Blood Collection Management	Preparation Operation Standardization	Equipment Maintenance	Material and Storage/Transport Management	Comprehensive Score
Control Group (n=991)	86.35 \pm 2.26	84.71 \pm 2.83	82.93 \pm 2.94	83.52 \pm 3.18	84.38 \pm 2.79
Experimental Group (n=993)	95.64 \pm 1.84	96.18 \pm 1.56	94.83 \pm 1.97	95.33 \pm 1.65	95.50 \pm 1.71
t-value	100.411	111.824	105.927	103.857	107.054
<i>P</i> -value	<0.001	<0.001	<0.001	<0.001	<0.001

4. Discussion

Blood component preparation is one of the most technically demanding processes in blood station operations

and has a direct impact on blood utilization ^[6]. After collection, blood must undergo separation and rapid freezing within a specified time frame, and variations in operator proficiency, equipment performance, ambient temperature, and humidity control can all affect the quality of the final blood products ^[7]. Although blood stations have implemented strict testing procedures in the preparation process, their management mechanisms have primarily relied on post-event control, lacking comprehensive norms for real-time supervision during the process. While this approach can achieve certain results, it struggles to provide real-time warnings and corrections for process fluctuations in a timely manner. As the public's demand for the safety of blood transfusion rises today, the quality management of preparation also needs to be improved accordingly. In this regard, the current whole-process quality control management involves setting standardized parameters and recording requirements in processes such as collection, separation, heat sealing, quick freezing, storage, and transportation. The application of this model helps eliminate differences caused by human factors and enhances the consistency and stability of finished products ^[8].

The results of this study show that the qualification rate of the experimental group implementing quality control management increased from 91.21% to 99.19%, while the rejection rate decreased from 9.18% to 0.81% compared to the control group under conventional quality management ($P < 0.05$). By comparing the specific measures of the two management models, it is not difficult to identify the reasons for this improvement. Due to the adoption of dual parameter confirmation and balance verification during the centrifugation process in quality control management, the stratification of red blood cells in the blood becomes more stable. Meanwhile, equipment such as heat sealers and quick freezers is maintained and calibrated as planned, which largely avoids leakage and contamination caused by temperature deviations or poor heat sealing. Additionally, operators improve their adherence to execution standards through systematic training and assessment, significantly reducing subjective randomness in the preparation process. These results are consistent with the research conclusions of Mao Qichao et al., who believed that adjusting the quality control plan for blood component preparation can effectively improve the qualification rate of spot checks ^[9]. Furthermore, the results also show that the abnormal event rate at each control point in the experimental group was significantly lower than that in the control group, and the handling time was significantly shortened ($P < 0.05$). This may be because a real-time recording and quality control feedback mechanism is established in quality control management, enabling operators to promptly identify and handle abnormalities at the early stage of problems, greatly reducing event accumulation and cross-impact. Finally, the results also indicate that the experimental group scored higher overall in work quality evaluations ($P < 0.05$), suggesting that the effects of quality control management not only improve preparation results but also further enhance the overall execution capability and management maturity of the team. This result is consistent with the research findings of Li Yingping et al., both concluding that the adoption of quality control management in blood component preparation at blood stations can effectively improve work quality ^[10].

In summary, quality control management throughout the entire process of blood component preparation can reduce waste caused by human errors and equipment failures at the source, enhance preparation efficiency and consistency of finished products, and improve the overall quality of blood products. In the future, it is essential to integrate information technology or tools to conduct real-time monitoring and trend analysis of key parameters involved in the process, thereby gradually establishing an intelligent quality control system and providing more reliable technical support for the safety of clinical blood transfusions.

Disclosure statement

The authors declare no conflict of interest.

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Research Progress of Ski Jumping Training Theory and Preparation Strategy for the Milan Winter Olympics

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Abstract: Current research on ski jumping predominantly employs sports biomechanics to describe the kinematic and dynamic characteristics of athletes' takeoff and flight phases, yet lacks a systematic synthesis of training theory advancements and consideration of competition preparation strategies. This study employs literature review, expert interviews, and fieldwork to comprehensively analyze domestic and international ski jumping research and training requirements, so as to provide references for the Milan Winter Olympics from aspects such as competition rules, technical characteristics, and preparation strategies. The research results reveal that the takeoff-early flight phase is the decisive segment of the entire movement process, where technical proficiency directly impacts final performance. The key technical challenge during the takeoff phase is how to rapidly elevate the center of gravity to generate forward angular momentum while maintaining proper posture to counteract air resistance. Although a higher takeoff speed can reduce launch time, impair athletes' control over their movements. Therefore, an adaptive choice between higher speeds and better technical control should be made based on individual athletes' specialized control capabilities. During the flight phase, vertical velocity demonstrates a more significant influence on performance compared to horizontal velocity, while angular parameters show a greater impact than relative velocity parameters. CFD calculations indicate that surface pressure acting on athletes' bodies has a far greater aerodynamic effect than air resistance. The optimal ski board angle of 24-3° was determined through L/D ratio analysis. To meet the needs of the four core technical phases of ski jumping, it is necessary to introduce leveraging low-speed return wind tunnels for environmental simulation, wearable devices for posture testing, and multi-parameter physiological monitoring, and construct athletes' multi-parameter digital twin models. These measures can provide support for their preparation for the Milan Winter Olympics.

Keywords: Ski jumping; Sports biomechanics; In-run; Take-off; Early flight

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1. Preface

Ski jumping originated in Norway and spread to countries including Sweden, Switzerland, the United States, France, and Italy by the late 19th century. It was officially included as an event in the 1924 Chamonix Winter Olympics, making it one of the longest-standing snow sports in competitive history. This sport has three defining characteristics: (1) Short duration — the entire process from takeoff to landing takes just over ten seconds; (2) Extreme vertical drop — athletes descend over 100 meters vertically with approximately 100 meters of horizontal distance; (3) High-speed performance — maximum downhill speeds exceed 100 km/h; (4) Intense physical demands — athletes must maintain balance and execute precise transitions between in-run, takeoff, mid-air maneuvers, and landing postures; (5) Significant drag resistance — strong crosswinds in mountainous terrain create substantial pulling forces. These unique characteristics impose exceptionally high and specialized requirements on athletes' training regimens and competition preparations.

Given the high technical difficulty and competitive risk in ski jumping, this sport has required scientific validation and technological support for every advancement since its inception. This includes technical innovations—from “traditional in-run techniques” to “V-shaped in-run techniques”, from “parallel double-board flight techniques” to “V-shaped flight techniques”, and from “two-foot landing techniques” to the “Taylor-Mack landing technique”; as well as equipment upgrades like improved ski suit materials, evolved ski board designs, and refined waxing techniques. The ski jumping sport's development in China started relatively late, with the national team officially established in 2017. In the Beijing Winter Olympics, seven athletes qualified for the competition, marking the first-ever coexistence of male and female participants. Although all seven athletes ultimately failed to advance beyond the qualification round, this achievement represented a breakthrough for the five-year-old national team.

Chinese scholars have primarily focused their research on ski jumping's kinematics, dynamics, fluid mechanics, aerodynamics, and computer simulations, while few have focused on its training characteristics and competition preparation strategies. This study adopts a sports training perspective, systematically discussing three key issues: the evolution of competition rules, specialized technical features, and technology-assisted training strategies. It synthesizes the training principles of ski jumping, equips frontline coaches with essential training knowledge, and addresses competition demands. The findings provide theoretical support for enhancing the scientific rigor and safety of training and preparation plans for the Milan Winter Olympics. In the training process, lower limb explosive power, body coordination, core control ability, and so on are put forward with very high requirements. Additionally, it is expected to provide a reference for the majority of scholars to further understand the international high-level ski jumping training theory, training key, and training needs.

2. Specialized technical features

For a long time, Chinese scholars have focused on simulation studies such as CFD calculations in ski jumping research. In recent years, researchers like Hu Qi and Liu Yu have conducted studies on aerodynamic advancements in ski jumping, the impact of ski angle and body posture asymmetry on aerodynamic characteristics during the flight phase, and summarized the influence of ballistics, aerodynamics, and fluid mechanics on ski jumping techniques both domestically and internationally^[1-3].

Ski jumping is a non-periodic sport comprising a series of coordinated movements. Based on technical characteristics, it can be divided into four phases: in-run, take-off, flight, and landing, each with distinct technical

priorities^[1,4]. The in-run phase aims to maximize initial take-off velocity. The take-off phase focuses on generating maximum kinetic energy for aerial flight. During flight, the key is to optimize body control for maximum aerodynamic lift, enabling longer distances. The landing phase emphasizes a safe and stable touchdown in the Mark Taylor position, with the goal of achieving the highest technical landing score.

A review of literature spanning nearly three decades reveals that the previous ski jumping research mainly focused on different disciplines depending on the phase of the movement. Take-off is primarily studied through ballistics, while aerial flight involves aerodynamics research^[1,3,5-6]. Most aerodynamic studies are conducted in wind tunnels, where researchers simulate the movement process by adjusting wind speed and direction, then use computer algorithms to optimize an athlete's posture. The propulsive force generated during the take-off push-off is the focus of dynamics research^[7-8]. Throughout the entire movement, particularly in the early flight phase, studies concentrate on kinematics^[1,5,9-14]. Notably, the take-off-to-early flight phase is the decisive stage of the entire movement, where the quality of techniques directly impacts the final outcome.

2.1. In-run

The flight techniques in ski jumping are categorized into traditional two-ski flight and V-shaped flight, with distinct corresponding in-run postures^[15].

Comparing two takeoff techniques, the traditional in-run features a narrow trunk-to-runway angle of approximately 0–5°, nearly parallel to the runway, with knee angles (β) of 65–75° and ankle angles (γ) of 55–65° (**Figure 1**). This technique positions the hips higher, allowing the body's center of gravity to remain at the front of the takeoff stance. The larger knee angle reduces the extension range during the takeoff phase, thereby facilitating a quicker jump and increased speed. However, the shorter extension distance limits full muscle power release. Additionally, the narrow trunk angle requires rapid post-takeoff posture adjustment to meet flight demands, prolonging the transition from takeoff to stable flight. Finland's Matti Niikinäinen exemplifies this technique with his signature low takeoff stance and powerful jump, generating a force equivalent to 2.5 times his body weight.

The "V" shaped flight posture, exemplified by Swedish athlete Boklov, features a 20° trunk-to-runway angle, 55–65° knee flexion (β), and 45–55° ankle flexion (γ) (**Figure 1**)^[16]. This technique optimizes the transition between takeoff and flight stability. Its forward-leaning takeoff direction, slightly elevated upper body posture, and reduced hip flexion with increased knee and ankle flexion enhance performance. The advantages are as follows: it maximizes knee extension to harness takeoff power, and its upper body alignment closely matches flight requirements without major adjustments.

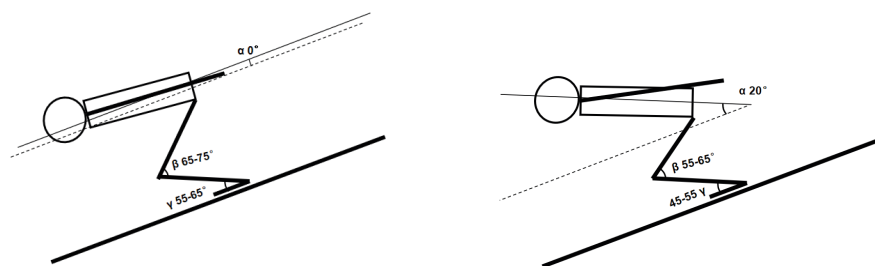


Figure 1. Comparison of in-run phases between the traditional two-board technique (left) and the V-shaped technique (right)

2.2. Take-off

In ski jumping, performance is primarily evaluated based on athletes' flight distance and technical execution. As the sport relies on a human open-loop control system, the irreversible nature of movements requires precise control at every phase. The take-off phase serves dual purposes: it builds momentum from the in-run and powers the flight phase. The quality of this phase directly determines the athlete's overall jump performance^[4, 17]. Factors influencing take-off include the athlete's physical strength, coordination, and environmental elements like wind speed, direction, and equipment. Diagnosing the take-off technique from a biomechanical perspective facilitates its optimization.

The purpose of ski jumping takeoff is to elevate the center of gravity and generate forward angular momentum, maintain proper posture to counteract resistance, and sustain body balance during flight^[4, 18]. As the run phase concludes, the track's curvature gradually diminishes, with gravitational potential energy from the run phase progressively converting into forward kinetic energy, increasing the centripetal force the athletes experienced^[17]. In the initial takeoff phase, athletes extend their bodies using the centripetal force from the semi-squat run position, shifting their center of gravity forward. During this stage, the sacrum and femur simultaneously rotate toward the front, with the thigh's angular velocity exceeding that of the lower leg, resulting in increased knee joint angle. As lower limb extension completes, the lower leg's rotational angle increases^[18]. Research indicates that the increased lower leg angular velocity compensates for body sway caused by rapid knee extension, making smaller lower limb movements advantageous for enhancing angular momentum^[19–20]. This conclusion aligns with Virnavirta's findings that elite athletes employ coordinated techniques with minimized lower leg movements and trunk-femur coordination^[18]. In the final phase of takeoff, the sacrum exhibits greater angular velocity than other lower limb joints, driving the thigh to generate forward angular velocity and propelling the body forward into the initial flight phase^[18]. Zanevskyy's team demonstrated that ski jumpers' ankle, knee, and hip joint angles, body posture angles, and body attack angles are significantly correlated with takeoff distance^[21]. Virnavirta et al. also found that hip and knee angular velocities are crucial for takeoff distance^[19]. During takeoff, pressure in the big toe region increases markedly, reaching peak values among the three zones simultaneously. Electromyographic parameters indicate that high contribution rates from the vastus lateralis and gluteus maximus muscles (**Figures 2–3**)^[7]. These studies highlight that kinematic parameters of lower limb joints (hip, knee, and ankle) provide critical diagnostic value for athletes' takeoff techniques. Moreover, efficient momentum transfer through the body's kinetic chain during takeoff enhances ski jumping performance.

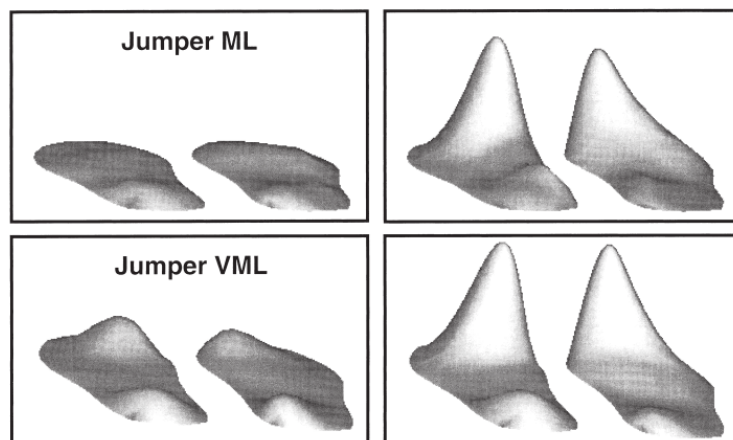


Figure 2. Pressure diagram of two athletes at the initial phase of in-run and the instant of take-off. This figure is adapted from the study by Mikko Virnavirta^[7].

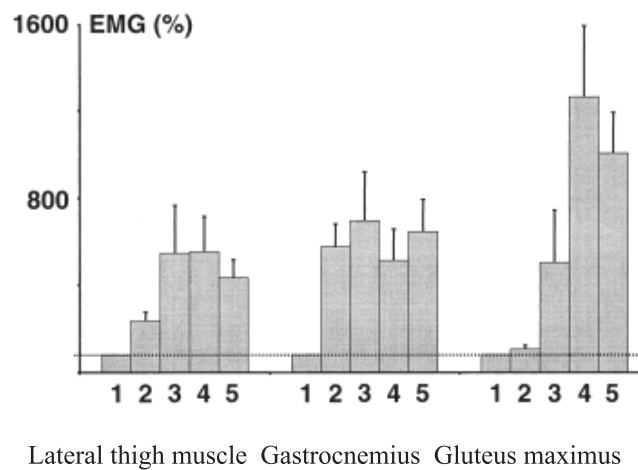


Figure 3. Average muscle work during the glide phase (periods 1 and 2) to take-off (periods 3 to 5). This figure is adapted from the study by Mikko Virmaavirta ^[7].

Except for athletes' technical execution, aerodynamic factors during flight significantly impact ski jumping performance ^[21]. With the evolution of techniques, the traditional parallel ski technique has been replaced by the "V" technique, as it generates greater air assistance during flight ^[22]. Achieving an optimal lift-to-drag ratio during takeoff is crucial for success, with individualized ski angle and joint positioning determined by each athlete's physique ^[23]. After leaving the run, athletes experience three primary forces: gravity, lift, and drag. Effective aerodynamic control hinges on lift direction management. Mountain wind conditions dramatically shorten takeoff time compared to the factors of indoor environments ^[8]. Virmaavirta notes that higher takeoff speeds impair movement control, making it harder to balance body position with wind speed during actual competitions ^[7]. Crosswinds and asymmetric force application during takeoff increase initial velocity deflection angles relative to ski direction, creating lateral yaw forces that hinder optimal speed utilization and body posture scoring ^[2]. Research reveals that surface pressure affects aerodynamics more than air resistance, while taller athletes do not necessarily face greater drag ^[1]. During movement, the separation of airflow behind the head and hands tends to create low-velocity zones, which hinder lift generation ^[24]. Research on elite athletes reveals that while a larger trunk angle during takeoff increases air resistance, the short duration of this phase may not necessarily compromise flight distance ^[4]. This suggests that the takeoff stage's critical success factors lie in optimizing lift acquisition and elevating the center of gravity, with an appropriate trunk angle being pivotal for lift generation. These findings provide theoretical guidance for ski jumping athletes' training.

During the takeoff phase, athletes experience combined forces from air lift (L), air resistance (D), gravity, and friction. The air lift and drag forces are directly related to the takeoff posture. International wind tunnel studies on ski jumping predominantly use scaled human models. Cutter's aerodynamic research on the "V" shaped flight pattern involved scaling the human body at a 1:5.5 ratio and conducting wind tunnel tests, and found that an optimal lift-to-drag ratio of 22.5° V angle, 20° angle of attack, and $L/D=1.55$ ^[25]. Guan Ruhua et al. applied multi-rigid-body system dynamics and mathematical programming methods to analyze decisive factors in the takeoff stage. By combining the principle of momentum moments, ski jumping technical requirements, and human physiological conditions, they identified relative angles of body segments (captured through high-speed video) as key variables. This led to the derivation of nonlinear equations (NP(j)) for calculating the center of mass's

horizontal/vertical velocity and takeoff angle at the moment of impact. Using Li Baoquan, a two-time National Winter Games champion in ski jumping, as a case study, they concluded that Li's adoption of the "II" takeoff technique performed better^[26].

2.3. Flight phase

Research on the kinematics of ski jumping during the early flight phase can be categorized into two in-runs. The first one treats the human body as a mass center, analyzing its altitude, horizontal velocity, and vertical velocity along the trajectory. While conventional theory suggests that a higher flight posture contributes more to distance, Mikko Virmaavirta's team found that top competitors maintained significantly lower postures than others. This discrepancy may be directly linked to the competition venue's high altitude (> 2000 m), low air density, and reduced buoyancy^[11]. The study conclusion indicates that in low-density air environments, maintaining optimal speed during flight is crucial for performance. Arndt's research on the 1994 Winter Olympics K90 individual event athletes found that, through early flight phase analysis, trajectory parameters (altitude and velocity) did not significantly influence total flight distance^[12]. Du Yunyun's study demonstrated that increased horizontal and vertical initial velocities both extended flight time and distance. Vertical velocity had a more pronounced effect on flight duration, while horizontal velocity showed greater impact on distance. The findings highlight that higher horizontal initial velocity has a more substantial influence on ski jumping performance^[27]. Fuli scholars applied multibody system dynamics to model ski jumpers as a tree-structured multibody system with finite hinges. Using tensor-matrix relationships, they developed a four-body mechanical model, derived the system's center-of-mass dynamics equations and attitude equations, and ultimately created the Program for Human Body Dynamics in Flight (PHBD) for computational analysis^[28].

Another category focuses on studying human body posture during sports, conducting independent research on angular parameters, velocity parameters, and distance parameter changes of body segments in the air. Compared to angular and velocity parameters, research on distance parameters remains scarce, with only a few metrics mentioned. Arndt's study specifically noted the distance between snowboards, demonstrating a correlation coefficient of $R^2 = 0.84$ when analyzing five customized flight angles at 17 meters post-launch. Among these angle parameters, trunk posture showed the highest individual value with an $R^2 = 0.77$. Examining both angular and center-of-mass velocity parameters in this study reveals that a more compact body position (i.e., "V"-shaped flight posture) within the first 5 meters post-launch provides favorable conditions for initial flight speed. For the subsequent flight phase, an extended body posture offers greater aerodynamic lift^[12]. Mikko Virmaavirta et al. investigated the correlation between horizontal and vertical velocities during the first 1.6 seconds of flight and performance outcomes^[11]. Their findings indicate that horizontal velocity showed no significant correlation with performance at the instant of takeoff, while vertical velocity demonstrated a more pronounced correlation. This discrepancy may relate to athletes' rapid descent during the takeoff phase, contradicting Du Yunyun et al.'s findings^[27]. This inconsistency could be directly associated with adaptive body posture adjustments during actual takeoff on ski jumping platforms. Through these studies, we can infer that vertical velocity exhibits a more significant correlation with performance compared to horizontal velocity. Some scholars argue that angular parameters contribute more significantly to performance than relative velocity parameters^[6, 11–14]. This indicates that athletes' body posture control and technical execution during movement are decisive factors for performance outcomes. The skislope angle affects the aerodynamic characteristics of the skier-board system, with a $24\text{--}32^\circ$ range being identified as the optimal angle through CFD simulations and L/D ratio analysis^[3].

The angle parameters can be divided into two categories:

(1) Internal Relationships of the Human-Board System. Common angle parameters include:

- (a) Body posture angle: The angle between the line connecting the ankle and the cervical vertebrae and the ski board—considered the most significant indicator related to jump distance, especially during the first 0.1 seconds and the latter half of the early flight phase 0.6–1.6S. Therefore, it is believed that the ski board should be lifted immediately after takeoff, and during the later part of the early flight phase, the ski board should be as close to the body as possible;
- (b) Trunk angle: The angle between the line connecting the hip joint and the cervical vertebrae and the ski board;
- (c) Body lean angle: The angle between the line extending the tibia and the ski board, which in some studies is indicated by the angle between the line connecting the cervical vertebrae and the ankle and the ski board;
- (d) Leg abduction angle: The angle between the two legs;
- (e) Ski board angle: The angle between the lines extending the two ski boards, also known as the “V” angle. See **Figure 4** for details.

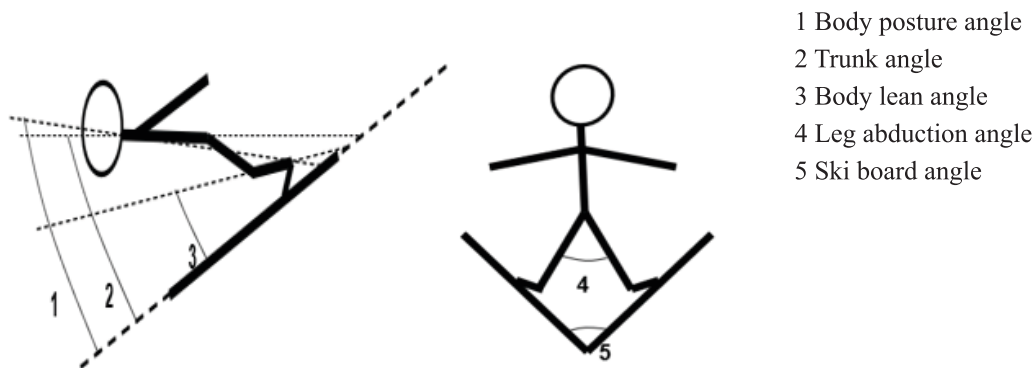


Figure 4. Internal relationship angle of the human-board system

(2) Body Segments and External Relations. Key angle parameters include:

- (a) Snowboard attack angle: defined as the angle between the snowboard and the instantaneous velocity direction;
- (b) Lower limb attack angle: defined as the angle between the tibial extension line and the instantaneous velocity direction;
- (c) Flight angle: the angle between the instantaneous velocity direction and the horizontal plane;
- (d) Snowboard position angle: the angle between the snowboard and the horizontal plane;
- (e) Lower limb angle: the angle between the ankle-cervical spine line and the horizontal plane;
- (f) Trunk angle: the angle between the hip-cervical spine line and the horizontal plane. See **Figure 5** for details.

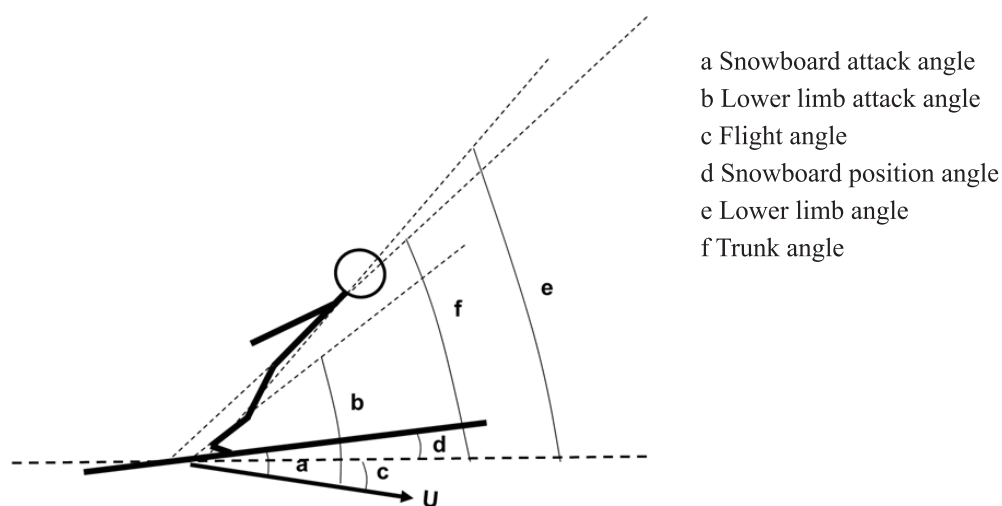


Figure 5. Body segments and external relationship angles

3. Strategies for technology-assisted training

3.1. Conducting simulation training

Due to the limitations of the actual ski jumping environment, training on real ski jumps is inefficient. Indoor training using simulated ski jumps can enhance effectiveness. Current indoor ski jumping training primarily involves take-off practice with roller skis and wind tunnel simulations to improve subjective perception ^[24, 29]. The key to ensuring training quality depends on simulating both the actual ski jump environment and movement patterns, which requires exploring similarities and differences between indoor training and real ski jumps to optimize training methods. The primary distinction between indoor training and real ski jumps lies in fluid dynamics. Without the speed generated during the in-run phase, athletes' simulated take-off initial velocity cannot match the required aerodynamic speed, resulting in lower lift utilization during indoor take-offs ^[30]. The lower take-off speed also makes decision-making during indoor training less challenging compared to real ski jumps. With technological advancements, wind tunnel training can effectively simulate real ski jump conditions, but the difference in speed perception still needs to be reflected in actual ski jump training. Studies show that real ski jumps have earlier take-off times than simulation ones, indicating that speed perception differences may affect athletes' decision-making capabilities ^[31]. Besides the fluid dynamics, there are also differences in equipment between indoor and real ski jumps. The most significant distinction lies in the ankle joint restrictions between indoor training shoes and ski boots. The greater stiffness of ski boot uppers limits plantar flexion during take-off, hindering the extension needed for push-off and causing forefoot pressure to shift forward, thereby restricting vertical force generation ^[23]. While indoor training differs from actual ski jumping, the controlled environment of indoor facilities effectively enhances athletes' technical execution ^[30, 32]. Extensive research confirms that increased muscle strength and loading rates in hip and knee extension muscles significantly improve athletic performance ^[23, 32]. It was proven that performing 80%1RM bodyweight squat jumps after 60%–80%1RM muscle activation optimally recruits motor units for maximum training effectiveness ^[33]. Studies on elite athletes' takeoff techniques reveal that top ski jumpers achieve more coordinated takeoff states compared to average athletes, with these differences being particularly evident in indoor training ^[31]. Additionally, rehabilitation methods targeting weak

links in the takeoff kinetic chain demonstrate significant improvement^[34]. These findings collectively reflect the diversification of ski jumping training methodologies.

3.2. Weight control

Zhang Guizhen and others found that through studying the competition results and influencing factors of ski jumpers, excellent ski jumpers generally have lighter body weights. Apart from developing the necessary lower limb (mainly around the knee joints) muscle strength, they almost do not increase the weight of upper limb and trunk muscles. They believe that the ratio of height (cm) to weight (kg) can be used as a standard. The range of the ratio of height (cm) to weight (kg) for athletes is 2.95 ± 0.5 , with 2.90 being the minimum excellent standard, 2.95 being the higher excellent standard, and 3.0 being the optimal standard, which aligns with the conclusions of Liu Shuming and others^[4, 35]. Park Xuefeng and others proposed the view that the lighter the body weight, the better, without reducing specialized strength^[36]. B. Scholer, Adrien Sedeaud, Wolfram Muller, et al., all studies show that as athletes' body weight decreases, their ski jumping performance in distance significantly improves^[37–40]. This is also one of the important reasons why ski jumpers have chosen lower body weights over the past decade, with some athletes even having a BMI of 16.6 kg/m^2 .

To prevent athletes from excessively losing weight to gain longer jump distances, the International Ski Federation (FIS) established a Body Mass Index (BMI) requirement in 2004, which mandates a BMI of at least 20 and limits the maximum ski length to 146% of the athlete's height^[19]. These regulations reduced the impact of body weight and equipment on jump performance, indirectly emphasizing the importance of technical execution during takeoff. Mikko Virma-virta noted that an athlete's weight had a more significant effect on jump results than ski length^[41]. A comparative analysis by Luca Oggiano et al. of 1970–2006 data revealed that ski jumpers' average BMI dropped from over 23 to below 20, indicating that the trend toward weight management to enhance performance persisted even after the FIS's new rules were implemented^[42].

3.3. Strengthening fatigue recovery

The improvement of athletes' training level follows a cyclical process of "fatigue-recovery-fatigue-recovery." Moderate exercise-induced fatigue, when managed with proper recovery methods, can enhance movement performance. However, excessive fatigue not only hinders athletic achievement but may also lead to sports injuries and even harm athletes' physical and mental health^[43]. Monitoring methods for exercise-induced fatigue include subjective evaluation indicators, physiological indicators, and biochemical indicators^[43–44]. Ski jumping requires athletes to maintain high levels of concentration, with fatigue in this sport predominantly being central fatigue^[45]. In physiological monitoring, flash fusion frequency (FFF) testing and electroencephalogram (EEG) can directly reflect central nervous system fatigue, providing insights into cerebral cortex activity during performance^[43–44, 46–50]. Despite its late development and limited scale in China, ski jumping has seen scant research in biological fatigue monitoring and medical supervision. This lack of scientific support not only complicates technological advancement but also leaves coaches without a scientific basis for training planning, significantly increasing the risk of sports injuries.

3.4. Enhancing technology-enabled support measures

In response to the specialized technical requirements of ski jumping across its four core phases, in-run, takeoff, in-flight, and landing, a low-speed return wind tunnel is adopted to simulate air density under different altitudes and

temperatures, as well as complex wind field conditions such as track crosswinds and updrafts. With the assistance of wearable devices, athletes can test the lift-drag ratio of various in-flight postures, increasing the lift-drag ratio of the optimal posture by 10%–15% and extending the airborne time by 0.3–0.5 seconds.

Wearable devices can collect data like Heart Rate Variability (HRV), Electromyography (EMG), and blood oxygen saturation. These data can be used to real-time assess athletes' central fatigue levels and muscle activation efficiency. If the HRV indicator drops by more than 15%, the training intensity is adjusted immediately. By establishing a specialized ski jumping data platform that integrates technical movement data, physiological monitoring data, and competition environment data (including track gradient, wind speed, and temperature), an athlete's digital twin model is constructed.

4. Discussion

The natural environment of ski jumping venues presents numerous uncontrollable factors. Due to venue limitations, current biomechanical research primarily focuses on the take-off and early flight phases, which are considered the most critical for performance. Most studies in this phase analyze take-off posture, while dynamic analysis of the flight phase remains limited, typically relying on foot pressure insoles or wind tunnel simulations. To establish the relationship between movement posture, pedaling force, and jump distance in real-world scenarios, this factor must be considered during the initial design of ski jumping venues.

During the take-off phase, the angles of the hip, knee, and ankle joints, body posture angle, and body attack angle all significantly impact the flight distance. Compared to the contribution of speed parameters to athletic performance, variations in angle parameters have a greater impact on final results. In the early flight phase of ski jumping, angle parameter selection is categorized into two main types: the internal relationship angle between the athlete and ski, and the external relationship angle between body segments and the environment. These two categories describe the proximity between the athlete and ski during flight, as well as the relative positions of the athlete/ski to the horizontal plane and velocity direction. Notably, the body posture angle and ski attack angle exhibit stronger correlations with flight distance.

Due to venue limitations and neural fatigue, ski jumping training sessions are often restricted in actual practice. Digital, intelligent, and integrated wind tunnel laboratories provide simulated environments for athletic training. Computational fluid dynamics (CFD) technology enables optimized postures that offer athletes the best reference for performance enhancement. Although the International Ski Federation (FIS) has established clear guidelines on body mass index (BMI) and the ratio of skis to body height, lower body weight can still contribute to technical performance in ski jumping. Therefore, weight management remains a crucial training aspect for athletes. However, research in China regarding fatigue relief methods, in-runs, and their effectiveness evaluation for ski jumpers remains limited, making this area a pressing research priority.

Compared with foreign research, the quantity, depth, and breadth of research on ski jumping in China are far from enough. It is expected that with the development of wearable devices, the research level of ski jumping venue testing and competitive performance will continuously enhance.

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Reconstructing the Value Chain of the Pet Food Industry Under the Dual Circulation Strategy: A Policy Synergy Practice Based on Multinational Enterprises

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Abstract: Against the backdrop of the sustained and deepened implementation of the “dual circulation” strategy, China’s pet food industry faces dual challenges of global value chain restructuring and localization transformation. This study investigates how multinational corporations use policy coordination to support the optimization of industrial value chains, investigating their strategies for overcoming trade barriers to international markets, deepening the local supply chains, improving the investment environment, and building industry ecosystems to achieve interlinked domestic and foreign trade-connected upgrades to industrial chains. The findings show that multinational enterprises have used policy coordination as a way to improve their competitive positioning in the marketplaces and resiliency of their supply chains, as well as promote high-quality industrial development through diffusion of technology and leadership on standards, which provides real examples of globalization and localization transformation of China’s pet food industry within the framework of “dual circulation.”

Keywords: Double circulation strategy; Pet food; Industrial value chain; Multinational enterprises; Policy synergy practice

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1. Introduction

The Chinese pet food market is growing rapidly due to both the upgrading of consumption and globalization, but it is also encountering problems related to supply chain security, the application of technical standards from older forms of food production technologies, and the lack of coordination between markets in a domestic and international Chinese context. The “dual circulation” strategy has charted a new path to an industrial upgrade based on the emphasis on the domestic cycle as the leading entity and the international circulation as a complement. As an important link between the domestic and international markets, multinational corporations in global commerce

can act as part of a policy coherence structure, which can help overcome the natural bottlenecks associated with industrial development. This analysis outlines cases of multinational corporations in areas such as market entry, local industrial integration, guided policy incentives, and coordinated industry self-regulation. The analysis seeks to offer theoretical references and practical implications for the sustainable development of China's pet food industry in the global competitive context that has multi-dimensional coordination, exploring how a fundamental theme of coordination can change the industrial value chain.

2. Theoretical framework

2.1. Global value chain and industrial upgrading theory

The key point of the global value chain theory is that the current production process is divided into multiple parts, which are dispersed across different countries. These links cover product research and development, raw material procurement, production and manufacturing, brand promotion, and after-sales service. There are two typical driving modes in the global value chain. The buyer-driven chain is mainly led by brand enterprises and retailers, and is more common in labor-intensive industries. For example, the pet food industry has significant buyer-driven chain characteristics, with value allocation biased towards brand operations and market channels.

The theory of industrial upgrading focuses on how enterprises advance along the value chain toward higher value-added segments. The upgrading process generally follows a trajectory from process improvement to product optimization, then to functional enhancement, and finally to cross-sector upgrading. In the pet food sector, functional upgrading is reflected in the shift from original equipment manufacturing (OEM) toward independent research and development and brand building. Such upgrading requires enterprises to accumulate technological capabilities, market insights, and brand influence.

Theories of global value chains and industrial upgrading provide a theoretical foundation for understanding industrial transformation within the context of the dual-circulation strategy. While allocating resources globally, multinational enterprises must align with the industrial policies and development needs of the host country. The upgrading of China's pet food industry reflects a shift among local enterprises from pure processing activities toward expanding into R&D, design, and brand management. Such transformation and development rely not only on the driving force of the market but also on support from the policy environment ^[1].

2.2. Theoretical interpretation and industrial impact of the “dual circulation” strategy

The “dual circulation” strategy is a pivotal decision made by China after thorough consideration of changes in development stages, environment, and conditions, particularly in response to shifts in comparative advantages. This strategy emphasizes prioritizing domestic circulation while fostering mutual support between domestic and international circulation. Its core focus is to enhance the stability of the internal economic system in order to address increasingly complex external conditions.

For the pet food industry, this indicates a shift in development priorities from previous scale expansion toward quality improvement and enrichment of intrinsic value. The main challenge faced by the industry is how to break free from low-level homogeneous competition and transition from “quantity-driven” growth to “quality-driven” advancement. Despite the current robust demand in the pet food market, structural imbalances persist—insufficient effective supply and excessive low-end offerings. The industry remains trapped in a vicious cycle of competition akin to “involution.” The key solution lies in comprehensively elevating industry standards, strengthening the

quality and safety system, and steering the sector from “traffic-driven” to “value-driven” development. This requires enterprises to focus not only on market share but also on product R&D innovation and brand value cultivation, meeting domestic consumers’ demand for premium pet food by improving supply chain efficiency and product quality.

In terms of international circulation, the “dual circulation” strategy requires the pet food industry to engage in global cooperation and competition at a higher level. The main obstacle faced by China’s pet food “going global” is the trade barriers it brings as an animal-derived product. Although the World Organization for Animal Health has indicated that the risk of spreading animal epidemics through commercially processed pet food is relatively low, there are still many restrictions on China’s international trade in this area. This shows that there is still room for further improvement in China’s bilateral or multilateral agreement negotiations on pet food trade, and the process of aligning with international standards needs to be accelerated. For multinational corporations, the “dual circulation” strategy provides them with unique development opportunities. They can leverage the advantages of optimizing global resource allocation, introduce advanced international technology and management experience into the Chinese market, and at the same time promote China’s domestic innovation achievements to the world. At present, some regions are actively exploring the use of the “cross-border e-commerce+industrial belt” model to open up global trade channels, helping pet food enterprises achieve the goal of “buying and selling nationwide and global goods.” This open industrial ecosystem not only helps to improve the internationalization of domestic industries but also adds new vitality to the global pet food market, ultimately building a virtuous development trend of domestic and international dual circulation mutual promotion.

3. Changes and challenges in the value chain of China’s pet food industry under the dual circulation strategy

3.1. Development status and trends of China’s pet food market

The Chinese pet food market is currently in an important period of transition from rapid growth to high-quality transformation. The role played by pets in the family has gradually evolved from a simple “life companion” to a “family member” with emotional attachment attributes. The transformation of this role has driven an upgrade in consumer demand, where consumers are no longer satisfied with the basic satiety function of the product, but are increasingly concerned about the scientific formula, functional ingredients, and raw material sources of the product. For example, young pet owners are more inclined to study protein and amino acid indicators in the ingredient list, while elderly pet owners place more emphasis on segmented functions such as joint maintenance and gastrointestinal regulation. The change in market demand has led enterprises to shift from pursuing scale expansion in the past to delving deeper into product quality, promoting the continuous increase in market share of high-end natural grains, grain-free grains, and other categories.

In order to adapt to the trend of consumption upgrading, the domestic pet food industry chain has accelerated the pace of cluster development, forming multiple regional industrial belts. Shandong, Hebei, and other regions have integrated upstream and downstream resources to build a complete industrial chain covering raw material supply, production and processing, and brand marketing. For example, Liaocheng has cultivated local leading enterprises with agricultural product resources and automated production lines, while Tai’an Pet Food Characteristic Town has transformed from “single production” to “coordinated development of the entire industry chain” by revitalizing idle land, attracting contract factories and research and development laboratories to

concentrate. These industrial clusters rely on shortening the transportation distance of raw materials and sharing testing facilities to reduce overall costs, while promoting the landing of innovative categories such as fresh meat, baked goods, and fresh steamed goods through technological cooperation.

In the future, industry competition will focus on areas such as technology research and development and global layout. On the one hand, enterprises improve the scientificity of their products by building their own laboratories and collaborating with universities, and on the other hand, actively explore international markets. Domestic brands are breaking through trade barriers through cross-border e-commerce and setting up factories overseas, gradually shifting from the OEM export model to the brand's overseas expansion model. With the continuous promotion of the dual circulation strategy, the industrial chain will further develop towards differentiation and intelligence, and the improvement of the regulatory system and the enhancement of standards will become an important foundation to support the sustainable development of the industry.

3.2. New opportunities and challenges brought by the “dual circulation” strategy

The “dual circulation” strategy has created a broader market space for the pet food industry, while also testing the strategic adaptability of enterprises. In terms of internal circulation, the trend of domestic consumption upgrading is quite significant, and the demand for high-quality and personalized products among pet owners continues to rise. This prompts companies to strengthen local research and innovation, and develop products that are more in line with the physical fitness of Chinese pets and consumer preferences. Faced with a complex international trade environment, enterprises need to enhance the resilience of their supply chains. Some enterprises have established industrial clusters domestically to ensure the stability of raw material supply and production. In the field of external circulation, Chinese pet food companies are shifting from OEM exports to brand going global. They use cross-border e-commerce platforms to directly connect with overseas consumers and actively participate in international standard certification to break down market access barriers ^[2].

In the process of strategic implementation, there are also numerous challenges, and enterprises need to find a balance point in complex environments. The fluctuation of the international trade environment has brought uncertainty to pet food exports, and some companies have begun to adjust their market layout by building factories overseas or exploring diversified markets to diversify risks. The competition in the domestic market is becoming increasingly fierce, and the competition between international and local brands in the high-end market is intensifying. Consumers' demands for product quality and safety continue to increase, and companies must continuously improve the transparency of their supply chain and their ability to trace product quality. Policy coordination has become the key to addressing these challenges. The pet industry park created through government enterprise cooperation provides supporting services such as customs clearance convenience and technical testing for enterprises, helping them better integrate into the dual circulation development pattern.

3.3. The core pain points of the current industrial value chain reconstruction

In the domestic circulation field, the pet food industry is facing a deep-seated contradiction between the demand for high-quality development and the unreasonable allocation of regulatory resources. The current market is in a difficult situation of “high demand, low trust”, and consumers' standards for pet food quality are constantly improving. However, the problem of product homogenization is prominent in the industry, with raw material use not meeting regulations and label labeling not being standardized. These situations have led to a setback in market confidence. The existing regulatory system is difficult to match the industry scale, and pet feed is managed by

agricultural and rural departments. Compared with the human food market regulatory system, there are differences in regulatory intensity and resource investment. The progress of improving the standard system cannot keep up with the pace of industrial development. Currently, there are not many national standards for pet feed, and most of them are basic standards. The standards for functional products, new raw materials, and other fields are almost blank. For example, common promotional concepts such as “fresh meat” and “raw food” do not have clear definitions, the constraint of recommendation standards is weak, and there is a lack of a strong basis for enterprise implementation. These factors combined hinder the innovation enthusiasm of high-quality enterprises, while low-quality products can still circulate in the market. The entire industry needs to break through the dilemma of shifting from scale expansion to quality competition ^[3].

In terms of international circulation, the main difficulty focuses on non-tariff trade barriers arising from animal epidemic prevention and control. Due to the characteristics of animal-derived raw materials, the import and export of pet food are strictly restricted by quarantine policies in various countries. Although the World Organization for Animal Health has indicated that the risk of spreading animal epidemics through commercial processed pet food is low and recommends the use of risk classification-based management methods, China still maintains relatively strict disease prevention and control requirements in pet food import and export management. There is a gap between this prevention and control requirement and the general international understanding. At the same time, the lack of bilateral trade agreements further increases the uncertainty of trade exchanges. Each batch of goods in the enterprise may face duplicate quarantine approvals, and supply chain collaboration and long-term planning are limited. For example, when Serbian pet health products enter the Chinese market, they must adjust the formula according to Chinese standards and reapply for admission, which is a time-consuming and costly process. This institutional barrier not only limits the deep participation of Chinese pet food companies in the global value chain but also affects the effective integration of international high-quality resources with the domestic market.

4. Policy coordination practices of multinational enterprises: Mechanisms and paths for driving value chain restructuring

4.1. Deeply cultivating domestic circulation: Promoting local industrialization and reshaping the midstream supply chain

In the process of restructuring the midstream supply chain in the pet food industry, multinational enterprises adopt local industrialization strategies to address issues related to raw material quality and supply stability. By introducing technology and collaborating with the domestic agricultural system, enterprises can promote the improvement of key raw material varieties and large-scale planting, thereby reducing dependence on imported raw materials ^[4].

The practice of local industrialization has significantly optimized the efficiency and resilience of the midstream supply chain. By creating an integrated chain of “research and development planting processing”, enterprises have integrated the raw material production process into domestic production areas, shortening the geographical distance of the supply chain. The large-scale production in China has reduced the cost of raw material procurement and logistics risks, allowing enterprises to respond more flexibly to market fluctuations. Pet food companies can refer to this model and promote the upgrading of other local raw materials, such as the localization of functional grains or animal protein sources, to further strengthen the independent and controllable ability of the supply chain.

4.2. Optimizing the investment environment: Guiding policy incentives and empowering downstream markets

Multinational corporations regard policy coordination as a core method to improve the investment environment. Enterprises actively engage in policy exchanges, promoting the inclusion of key business areas in the encouraged category directory, and creating a more favorable situation for expanding the market. In the past, there were many investment restrictions in service areas such as pet diagnosis and treatment. Enterprises systematically organize industry development trends and investment expectations, and communicate the actual needs of the market to policy-making departments. This policy exchange based on the current development status of the industry has promoted categories such as pet diagnosis and treatment to enter the list of industries encouraged for foreign investment.

The improvement of the policy environment is directly reflected in the enhancement of investment efficiency. Enterprises listed in the encouraged category can receive tax incentives and land policy support when investing in projects such as pet diagnosis and treatment. These tangible policy benefits have reduced the initial investment costs of new businesses and eased daily operational pressures. As a result, enterprises can quickly establish pet hospitals and professional channels in key cities and improve their service network for consumers. The positive effects of investment policy adjustments continue to expand downstream in the industrial chain. The establishment of pet diagnosis and treatment institutions provides a professional product display window and user education platform for pet food enterprises. Consumers are more likely to establish technical trust in brands in a professional service environment. The investment convenience brought by policy coordination actually helps enterprises build a complete value chain covering products and services, enhancing their comprehensive competitiveness in the local market.

4.3. Building a positive ecosystem: Leading industry self-discipline and enhancing long-term value

In the construction of the pet food industry ecosystem, multinational enterprises regard industry self-regulation as a crucial foundation for sustainable development. These enterprises have observed that some manufacturers engage in non-compliant practices during their marketing processes. Such approaches are likely to trigger public controversy and adversely impact the healthy development of the entire industry.

The practice of industry self-discipline has created a more stable development environment for enterprises. Standardized marketing practices reduce the risk of regulatory intervention and prevent the entire industry from facing policy restrictions due to excessive marketing by individual companies. Consumers show higher trust in companies that follow self-regulatory norms, which translates into brand loyalty. The overall image improvement of the industry has expanded the market space for all participants and formed a virtuous cycle. By actively constraining their own market behavior, enterprises actually provide strong guarantees for long-term profitability.

5. Business and social value assessment of policy coordination practice

5.1. Business value creation

In the framework of the dual circulation strategy, multinational pet food companies have achieved multi-level commercial value shaping through relevant practices of policy coordination. Enterprises are actively involved in the development of industry standards and the construction of self-regulatory agreements. Such actions enable companies to effectively avoid potential regulatory risks and reduce uncertainty factors caused by policy changes

in their business activities. With the help of policy coordination, enterprises can also obtain information on industrial policies earlier, thereby gaining time advantages in investment layout and market expansion. Some multinational enterprises have successfully promoted the inclusion of pet diagnosis and treatment businesses in the “Catalogue of Industries Encouraged for Foreign Investment.” According to this catalogue, enterprises have received tax incentives and land policy support, directly reducing the investment and operational costs of new businesses. The above practical activities have significantly enhanced the brand image of the enterprise. When companies actively follow business ethics standards that exceed basic requirements, consumers are more likely to identify them as responsible industry leaders. This trust will be transformed into brand loyalty, providing strong support for the long-term profitability of the enterprise. Policy coordination has also promoted the optimization of supply chain costs, such as reducing tariffs on key pet food raw materials, lowering raw material procurement costs for enterprises, and enhancing their price competitiveness in the end market. By participating in the construction of pet industry parks and utilizing the convenience measures of cross-border e-commerce, enterprises have further integrated the resources of the industry chain, expanded domestic and international distribution channels, and achieved an upgraded transformation from single product sales to a “product+service” ecosystem, thereby gaining sustained competitive advantages in the pet economy competition ^[5].

5.2. Social value contribution

The policy collaboration practice between multinational corporations and the pet food industry has created significant social value. These enterprises actively participate in the process of formulating industry standards, introducing advanced international pet food production standards and quality management experience into China. The relevant departments are organizing the development of mandatory national standards, such as “Pet Food Hygiene Standards” and “Pet Feed Labels”, as well as recommended national standards such as “Dog Nutrition Needs” and “Cat Nutrition Needs”. The practical experience of multinational enterprises provides a useful reference for these standards. Policy coordination has also helped enterprises make up for the lack of regulatory resources. The Ministry of Agriculture and Rural Affairs has implemented a production license and import registration system for pet feed in accordance with the “Regulations on the Management of Feed and Feed Additives.” Multinational enterprises have provided a model for the entire industry to learn from by building internal quality control systems that exceed basic requirements. These measures effectively enhance consumers’ trust in the pet food industry, allowing them to choose products that are suitable for their pets with more peace of mind. At the level of international trade facilitation, policy coordination promotes the deeper integration of China’s pet food industry into the global value chain. By promoting bilateral cooperation in the pet food trade and mutual recognition of standards, policy coordination has created more favorable conditions for Chinese pet food companies to expand into international markets. Multinational corporations have played a bridging role in this process, effectively connecting China’s pet food manufacturing capabilities with global market demand, while also introducing high-quality international products into the Chinese market, enriching the range of choices for domestic consumers. These social values collectively form the key foundation for the sustainable development of the pet food industry in the context of the dual circulation strategy, promoting the construction of a harmonious social environment between humans and pets.

6. Conclusion

Under the “dual circulation” strategy, the value chain reconstruction of the pet food industry is essentially a process of synergistic integration of global resources and construction of localization capabilities. Through policy collaboration, multinational corporations have not only achieved the business goals of supply chain optimization and market expansion, but also driven technological development and improved industry standards. In the future, industrial competition will rely more on in-depth exchanges between multinational corporations and local policies, as well as their long-term contributions in the fields of sustainable development and social responsibility. This path not only provides the driving force for the transformation and upgrading of the pet food industry, but also provides valuable experience for China’s agriculture and consumer goods industries to integrate into the global value chain.

Disclosure statement

The author declares no conflict of interest.

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Construction and Empirical Research on the Evaluation System of Equipment Support Capability for the China Coast Guard

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Abstract: Aiming at the special equipment support environment, complex task requirements, and insufficient scientificity of existing evaluation methods of the China Coast Guard (CCG), this study takes a directly affiliated bureau of the CCG as the research object to construct a targeted equipment support capability evaluation system. The Analytic Hierarchy Process (AHP) is adopted to determine index weights, and the fuzzy comprehensive evaluation method is integrated to establish an evaluation model. Empirical evaluation is conducted through field investigations, questionnaires, and statistical data collection. The results show that the comprehensive score of the bureau's equipment support capability is 3.32 points, reaching a "general" level. Among the five criterion layers, support resource allocation and support personnel quality perform relatively well, while support technology level and support management mechanism need further optimization. This evaluation system is scientific and feasible, providing theoretical support and practical reference for the refined management and systematic improvement of the CCG's equipment support capability, which is in line with the construction requirements of the modern military equipment management system.

Keywords: China coast guard; Equipment support capability; Evaluation system; Equipment management

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1. Introduction

The President of the CPC clearly pointed out at the All-Army Equipment Work Conference that building a modern weapon and equipment management system is a key support for realizing the centenary goal of building a strong military. This important requirement provides a fundamental follow for the equipment construction and management of all military services and arms. As the core law enforcement force stationed in coastal areas, the CCG undertakes important tasks such as maintaining maritime rights and interests, patrolling law enforcement, and emergency response. Its equipment support work faces prominent particularities: long-term exposure to high-temperature, high-salt, and high-humidity marine environments leads to severe equipment corrosion; the task

scenarios are diverse and complex, with varying requirements for support response speed and repair capabilities; the jurisdiction covers a wide range of offshore areas, reefs, and key ports, with complex meteorological and hydrological conditions, resulting in higher support difficulty than inland troops.

In current practice, the evaluation of maritime police equipment support capability still mostly adopts traditional methods. These methods have obvious deficiencies in terms of scientificity and standardization, making it difficult to objectively and accurately reflect the actual level of equipment support. Meanwhile, academic research on the special evaluation of maritime police equipment support capability is relatively lagging behind, and a mature and unified evaluation system has not yet been formed. This situation is incompatible with the functional requirements of maritime police forces. Therefore, combining the special operational environment and diverse mission requirements of maritime police equipment support, constructing a scientific and standardized equipment support capability evaluation system, and conducting an empirical study on a directly affiliated bureau of the CCG will have important theoretical significance and practical value for effectively improving equipment support efficiency and promoting the optimization of combat effectiveness generation models.

2. Characteristics and management status of equipment support in the coast guard forces

2.1. Characteristics of equipment support

High requirements for environmental adaptability: The high-temperature, high-salt, and high-humidity environment leads to a high incidence of equipment failures. In the past three years, equipment failures caused by marine environment corrosion accounted for 42% of the total failures in a directly affiliated bureau of the China Coast Guard, and extreme weather affected equipment on-duty for more than 35 days per year on average.

Diverse and complex task scenarios: It covers multiple tasks such as patrol law enforcement, maritime search and rescue, and emergency response. Different tasks have significantly different requirements for the response speed, repair capacity, and material supply of equipment support.

Wide and dispersed support scope: The average support radius of the jurisdiction is more than 80 nautical miles. The transportation of remote reef stations is inconvenient, and the average repair time for equipment failures is 48 hours, which is much higher than 12 hours for coastal main stations.

High technical specialization: Informationized equipment accounts for 65% of the total, involving multiple professional fields such as electronic information and naval architecture. However, personnel with maintenance qualifications for informationized equipment only make up 37.9% of the total support staff, resulting in a prominent shortage of technical talents.

2.2. Main problems in equipment support management

Through investigation, it is found that there are the following problems in the equipment support management of a directly affiliated bureau of the China Coast Guard: First, the performance management and capacity development of support personnel are unbalanced. The proportion of intermediate and above professional and technical titles is only 25%, the experience in complex equipment maintenance is insufficient, and the talent training and management system needs to be improved; second, the allocation and management of support resources are unbalanced. The maintenance equipment of reef stations is aging, the spare parts reserve is insufficient, and the mechanism for dynamic allocation and optimal configuration of resources is not sound; third, the application and management of support technology are lagging behind. The application rate of advanced diagnostic technology

is low, the information management system has not been fully built, and the integration of technology and management is insufficient; fourth, the process management of emergency support needs to be strengthened. The reserve of emergency spare parts is insufficient, the management mechanism for cross-regional collaborative support is not sound, and the standardized management level of emergency response needs to be improved; fifth, the system management of support work is not perfect. The management scientificity of the evaluation and incentive mechanism is insufficient, the training content is out of touch with the actual needs, and the management closed loop has not been fully formed.

3. Construction of the equipment support capability evaluation system for the Coast Guard forces

3.1. Theoretical basis of evaluation

3.1.1. Analytic hierarchy process (AHP)

AHP is a systematic analysis method that decomposes complex decision-making problems into a target layer, a criterion layer, and an index layer. By pairwise comparing the importance of each index, constructing a judgment matrix, conducting consistency tests, and calculating index weights, it effectively integrates qualitative and quantitative analysis, which is suitable for determining the weight of multi-level evaluation indexes ^[1-2].

3.1.2. Fuzzy comprehensive evaluation method

Based on fuzzy mathematics, it quantifies qualitative indexes by constructing a fuzzy evaluation matrix, and then conducts a comprehensive evaluation of the evaluation object. The core steps include determining the evaluation factor set and grade set, constructing a membership function, calculating a fuzzy evaluation matrix, and fuzzy synthesis operation. It can effectively handle the fuzziness and uncertainty in the evaluation process and is suitable for multi-index and multi-level comprehensive evaluation scenarios ^[3].

3.2. Principles for constructing the evaluation index system

Scientific Principle: The index system conforms to the objective laws of the Coast Guard's equipment support, comprehensively reflects the core elements of support capability, and the definition and calculation methods are scientific and reasonable.

Systematic Principle: This principle covers all aspects, including support personnel, resources, technology, management, and emergency response. The indicators are interrelated and complementary to each other, forming a complete evaluation framework.

Operability Principle: The indexes are concise and clear, and data can be easily obtained through questionnaires, field investigations, statistical statements, and other methods.

Targeted Principle: It highlights the special needs of the Coast Guard, such as the marine environment and diverse tasks, and designs indices in combination with the actual situation of a directly affiliated bureau of the China Coast Guard.

Dynamic Principle: The index system can be dynamically adjusted according to the development of equipment technology and changes in task requirements, optimizing index content and weight allocation to ensure timeliness and sustainability ^[4].

3.3. Specific content of the evaluation index system

According to the above construction principles and combined with the actual characteristics of the Coast Guard's equipment support, a three-level evaluation index system of "target layer — criterion layer — index layer" is constructed by using the literature method and interview method. The target layer is the comprehensive evaluation of the Coast Guard's equipment support capability; the criterion layer includes 5 dimensions: support personnel quality, support resource allocation, support technology level, support management mechanism, and emergency support capability; the index layer sets 19 specific indexes ^[1, 5]. The explanation of each index is shown in **Table 1**.

Table 1. Evaluation index system of equipment support capability for Coast Guard forces.

Goal Layer	Criteria Layer (Weight)	Indicator Layer (Weight)	Indicator Description
Comprehensive Evaluation of Equipment Support Capability of the China Coast Guard	Support Personnel Quality (0.25)	Professional Title Proportion (0.3)	Proportion of Support Personnel with Professional Titles at or Above the Intermediate Level
		Proportion of Personnel with Maintenance Qualifications for Informatized Equipment (0.25)	Proportion of Support Personnel with Maintenance Qualifications for Informatized Equipment
		Average Working Tenure (0.2)	Average Working Tenure of Support Personnel
		Training Assessment Pass Rate (0.25)	Annual Pass Rate of Training Assessment for Support Personnel
	Support Resource Allocation (0.25)	Support Station Coverage Rate (0.2)	Coverage Rate of Support Stations in the Jurisdictional Area
		Maintenance Equipment Availability Rate (0.25)	Proportion of Existing Maintenance Equipment in Good Condition
		Adequacy Rate of Regular Spare Parts Reserve (0.3)	Ratio of Actual Reserve Volume to Total Demand Volume of Common Spare Parts
		Funding Adequacy Rate for Support (0.25)	Ratio of Actual Support Funds to Budgeted Funds
	Support Technology Level (0.15)	Application Rate of Advanced Diagnostic Technology (0.35)	Proportion of Equipment Adopting Advanced Fault Diagnosis Technology
		Informatized Management System Coverage Rate (0.3)	Proportion of Support Businesses Implemented with Informatized Management
		Independent Repair Rate for Complex Faults (0.35)	Proportion of Independent Repair Completion for Complex Equipment Faults
	Support Management Mechanism (0.15)	Soundness of Rules and Regulations (0.3)	Improvement Level of Rules and Regulations Related to Support Work
		Improvement Level of Evaluation and Incentive Mechanism (0.25)	Scientificity and Operability of the Evaluation and Incentive Mechanism
		Targeted Level of Training Mechanism (0.25)	Matching Degree of Training Content with Actual Work Requirements
		Standardization of Fund Management (0.2)	Standardization Level of the Use and Management of Support Funds
	Emergency Support Capability (0.2)	Emergency Response Time (0.3)	Average Arrival Time at the Scene after Receiving an Emergency Support Task
		Reserve Rate of Emergency Special Spare Parts (0.25)	Ratio of Actual Reserve Volume to Total Demand Volume of Emergency Spare Parts
		Emergency Repair Success Rate (0.3)	Success Rate of Equipment Repair in Emergency Support Tasks
		Cross-regional Collaborative Support Capability (0.15)	Efficiency of Collaborative Emergency Support with External Units

3.4. Determination of evaluation index weights

The Analytic Hierarchy Process (AHP) is adopted to calculate the indicator weights following the steps below: constructing the judgment matrix → calculating the eigenvalues and eigenvectors of the judgment matrix → conducting the consistency test → performing the normalization process.

A total of 10 experts in the field of maritime police equipment support (including staff from equipment support departments, senior technical backbones, and frontline equipment user representatives) were invited to conduct pairwise comparisons of the indicators at both the criterion level and the indicator level using the 1–9 scale method, thereby constructing the judgment matrices.

3.4.1. The judgment matrix at the criterion level

The judgment matrix at the criterion level is presented in **Table 2**.

Table 2. Judgment matrix of the criterion layer

Criteria Layer	Support Personnel Quality	Support Resource Allocation	Support Technology Level	Support Management Mechanism	Emergency Support Capability
Support Personnel Quality	1	1	2	2	1.5
Support Resource Allocation	1	1	2	2	1.5
Support Technology Level	0.5	0.5	1	1	2/3
Support Management Mechanism	0.5	0.5	1	1	2/3
Emergency Support Capability	2/3	2/3	1.5	1.5	1

Step 1: Calculate the product of elements in each row of the judgment matrix M_i).

Multiply the elements in each row to obtain the row product M_i ($i=1,2,3,4,5$, corresponding to the 5 criteria)

$M_1(\text{Quality of Support Personnel}) = 1 \times 1 \times 2 \times 2 \times 1.5 = 6$

$M_2(\text{Allocation of Support Resources}) = 1 \times 1 \times 2 \times 2 \times 1.5 = 6$

$M_3(\text{Level of Support Technology}) = 0.5 \times 0.5 \times 1 \times 1 \times 0.6667 \approx 0.1667$

$M_4(\text{Mechanism of Support Management}) = 0.5 \times 0.5 \times 1 \times 1 \times 0.6667 \approx 0.1667$

$M_5(\text{Emergency Support Capability}) = 0.6667 \times 0.6667 \times 1.5 \times 1.5 \times 1 \approx 1$

Step 2: Calculate the n -th root of each row product (W' , the initial weight vector)

Given $n=5$, compute the 5-th root of M_i to derive the initial weight vector: $[\sqrt[5]{6} \quad \sqrt[5]{6} \quad \sqrt[5]{0.1667} \quad \sqrt[5]{0.1667} \quad \sqrt[5]{1}] = [1.4307 \quad 1.14307 \quad 0.7247 \quad 0.7247 \quad 1]$

Step 3: Perform normalization to obtain the final weights (W)

Sum up the elements of the initial weight vector W' , then divide each element by the total sum to generate the normalized weights (with the sum equal to 1).

$W = [0.25, 0.25, 0.15, 0.15, 0.2]$ (corresponding to Quality of Support Personnel, Allocation of Support Resources, Level of Support Technology, Mechanism of Support Management, and Emergency Support Capability, respectively).

Step 4: Consistency test (to verify logical rationality)

The SPSS software was employed to conduct a consistency test on the judgment matrix, calculating the maximum eigenvalue λ_{\max} , consistency index CI, and consistency ratio CR. The calculation results of the criterion-level judgment matrix are as follows: $\lambda_{\max}=5.02$, $CI=(5.02-5)/(5-1)=0.00$, $5CR=CI/RI=0.005/1.12\approx0.004<0.1$. The consistency test is passed, indicating that the judgment matrix is logically rational and the weight calculation is valid.

3.4.2. Indicator-level judgment matrix (taking the criterion of Quality of Support Personnel as an example)

Experts were invited to conduct pairwise comparisons of the 4 indicators: Proportion of Professional Technical Titles, Proportion of Personnel with Maintenance Qualifications for Informationized Equipment, Average Working Years, and Qualification Rate of Training Assessment, and the judgment matrix constructed is presented in **Table 3**.

Table 3. Judgment matrix for quality of support personnel indicators

Indicators for Quality of Support Personnel	Proportion of Professional Technical Titles	Proportion of Personnel with Maintenance Qualifications for Informationized Equipment	Average Working Years	Qualification Rate of Training Assessment
Proportion of Professional Technical Titles	1	1.2	2	1
Proportion of Personnel with Maintenance Qualifications for Informationized Equipment	0.83	1	1.8	0.9
Average Working Years	0.5	0.56	1	0.5
Qualification Rate of Training Assessment	1	1.11	2	1

The sum-product method, which is consistent with that applied at the criterion level, was adopted to calculate and verify the weights at the indicator level, following these steps:

1. Construct the indicator-level judgment matrix (Table 3);
2. Calculate the product of elements in each row and compute their 4th root to derive the initial weights;
3. Perform normalization to obtain the final indicator weights;
4. Conduct the consistency test ($\lambda_{\max}\approx4.03$, $CI=0.01$, $RI=0.90$, $CR=0.01/0.90\approx0.011<0.1$). The weight vector for the Quality of Support Personnel was finally determined as $W1=[0.3, 0.25, 0.2, 0.25]$.

The weights of other indicator layers were obtained in the same manner, with the results presented as follows:

Allocation of Support Resources: $W2 [0.2, 0.25, 0.3, 0.25]$, $\lambda_{\max}\approx4.02$, $CI=0.007$, $CR\approx0.008<0.1$; Level of Support Technology: $W3 [0.35, 0.3, 0.35]$, $\lambda_{\max}\approx3.01$, $CI=0.005$, $CR\approx0.009<0.1$; Mechanism of Support Management: $W4 [0.3, 0.25, 0.25, 0.2]$, $\lambda_{\max}\approx4.04$, $CI=0.013$, $CR\approx0.014<0.1$; Emergency Support Capability: $W5 [0.3, 0.25, 0.3, 0.15]$, $\lambda_{\max}\approx4.02$, $CI=0.007$, $CR\approx0.008<0.1$.

4. Empirical evaluation and result analysis

4.1. Evaluation implementation

Taking a directly affiliated bureau of the CCG as the evaluation object, the evaluation period is from September to

November 2025, which is divided into three stages: data collection, fuzzy evaluation, and result analysis.

4.1.1. Data collection and collation

Quantitative Data: Obtained from the bureau's equipment support statistical statements, including: the proportion of intermediate and above professional titles is 25.1%, the informatized equipment maintenance qualification rate is 37.9%, the average working tenure is 8.2 years, the training assessment pass rate is 92.8%; the support station coverage rate is 90%, the maintenance equipment availability rate is 90.3%, the regular spare parts reserve adequacy rate is 77%, the support funding adequacy rate is 95%; the advanced diagnostic technology application rate is 45%, the informatized management system coverage rate is 60%, the complex fault independent repair rate is 65%; the average emergency response time is 2.5 hours, the emergency spare parts reserve rate is 68%, the emergency repair success rate is 85%.

Qualitative Data: Obtained through questionnaires and field interviews. The evaluation team and front-line staff score qualitative indexes such as rules and regulations soundness. The evaluation grades are excellent (5 points), good (4 points), general (3 points), poor (2 points), and extremely poor (1 point), and the average score is calculated through statistical analysis.

4.1.2. Implementation of fuzzy comprehensive evaluation

Determine the evaluation grade set: $V=\{\text{excellent, good, general, poor, extremely poor}\}$, and the quantitative scores are $\{5, 4, 3, 2, 1\}$.

Considering the fuzzy characteristics of maritime police equipment support indicators (e.g., it is difficult to accurately quantify qualitative indicators such as the soundness of rules and regulations and the efficiency of collaborative support), the lower semi-trapezoidal distribution combined with the linear interpolation method was adopted to construct the membership functions. For quantitative indicators (e.g., the proportion of professional technical titles and the application rate of advanced diagnostic technologies), the membership degree was determined according to the ratio of the actual indicator value falling within the evaluation grade interval. For qualitative indicators (e.g., the soundness of rules and regulations and the pertinence of training mechanisms), the membership degree was determined based on the statistical results of grade scores from questionnaires (the proportion of votes obtained for each grade). Taking the criterion layer of Quality of Support Personnel as an example, its fuzzy evaluation matrix is shown as follows:

$$R1 = \begin{bmatrix} 0.1 & 0.3 & 0.4 & 0.15 & 0.05 \\ 0.05 & 0.25 & 0.45 & 0.2 & 0.05 \\ 0.2 & 0.35 & 0.3 & 0.1 & 0.05 \\ 0.3 & 0.4 & 0.25 & 0.05 & 0 \end{bmatrix} \quad (1)$$

Meaning of matrix elements: Each row corresponds to one indicator, and each column corresponds to the membership degree of the rating scale from Excellent to Extremely Poor. For instance, for the indicator Proportion of Professional Technical Titles in the first row, 10% of the data is classified as Excellent, 30% as Good, 40% as Average, 15% as Poor, and 5% as Extremely Poor.

Construction of the criterion layer for Allocation of Support Resources(R2): Based on the quantitative data of the 4 indicators (90% support station coverage rate, 90.3% maintenance equipment availability rate, 77% regular spare parts sufficiency rate, 95% support fund sufficiency rate) and supplementary qualitative rating scores, the

membership degree of each indicator was calculated via the membership function, thus forming the matrix as follows:

$$R2 = \begin{bmatrix} 0.2 & 0.4 & 0.3 & 0.1 & 0 \\ 0.18 & 0.35 & 0.37 & 0.1 & 0 \\ 0.15 & 0.3 & 0.38 & 0.15 & 0.02 \\ 0.2 & 0.37 & 0.33 & 0.1 & 0 \end{bmatrix} \quad (2)$$

Construction of the criterion layer for Level of Support Technology (R3): Based on the quantitative data of the 3 indicators (45% application rate of advanced diagnostic technologies, 60% coverage rate of information-based management systems, 65% independent repair rate for complex faults), combined with the qualitative ratings from technical experts, the membership degrees were calculated to form the matrix as follows:

$$R3 = \begin{bmatrix} 0.05 & 0.2 & 0.45 & 0.25 & 0.05 \\ 0.08 & 0.22 & 0.43 & 0.2 & 0.07 \\ 0.1 & 0.24 & 0.47 & 0.15 & 0.04 \end{bmatrix} \quad (3)$$

Construction of the criterion layer for Support Management Mechanism (R4): Based on the questionnaire survey results (the proportion of votes received for each grade) of the 4 qualitative indicators (including the soundness of rules and regulations and the improvement level of the evaluation and incentive mechanism), the membership degrees were determined to form the matrix as follows:

$$R4 = \begin{bmatrix} 0.12 & 0.28 & 0.42 & 0.15 & 0.03 \\ 0.1 & 0.25 & 0.45 & 0.18 & 0.02 \\ 0.13 & 0.3 & 0.4 & 0.14 & 0.03 \\ 0.11 & 0.29 & 0.43 & 0.16 & 0.01 \end{bmatrix} \quad (4)$$

Construction of the Criterion Layer for Emergency Support Capability (R5): Based on the quantitative data of the 4 indicators (including 2.5-hour emergency response time, 68% emergency spare parts reserve rate, etc.) and the qualitative ratings of collaborative support efficiency, the membership degrees were calculated to form the matrix:

$$R5 = \begin{bmatrix} 0.15 & 0.3 & 0.38 & 0.14 & 0.03 \\ 0.12 & 0.28 & 0.4 & 0.17 & 0.03 \\ 0.18 & 0.32 & 0.36 & 0.13 & 0.01 \\ 0.1 & 0.25 & 0.42 & 0.18 & 0.05 \end{bmatrix} \quad (5)$$

Fuzzy synthesis operation: The weighted average method is used to calculate the comprehensive evaluation vectors of the criterion layer and target layer. The comprehensive evaluation vectors of the criterion layer are:

$$B1 = W1 \times R1 = [0.1625, 0.325, 0.35, 0.1375, 0.025]$$

$$B2 = W2 \times R2 = [0.18, 0.33, 0.34, 0.12, 0.03]$$

$$B3 = W3 \times R3 = [0.08, 0.22, 0.45, 0.2, 0.05]$$

$$B4 = W4 \times R4 = [0.12, 0.28, 0.42, 0.15, 0.03]$$

$$B5 = W5 \times R5 = [0.15, 0.3, 0.38, 0.14, 0.03]$$

The comprehensive evaluation vector of the target layer is:

$$B=[0.25, 0.25, 0.15, 0.15, 0.2] \times [B1, B2, B3, B4, B5]^T = [0.143, 0.293, 0.369, 0.146, 0.039] \quad (6)$$

4.1.3. Quantification of evaluation results

Comprehensive evaluation score = $0.143 \times 5 + 0.293 \times 4 + 0.369 \times 3 + 0.146 \times 2 + 0.039 \times 1 = 3.32$ points. According to the evaluation grade standards (4.5–5 points for excellent, 3.5–4.4 points for good, 2.5–3.4 points for general, 1.5–2.4 points for poor, 1–1.4 points for extremely poor), the comprehensive evaluation grade of the bureau's equipment support capability is "general."

4.2. Analysis of evaluation results

4.2.1. Analysis of the criterion layer

Support Personnel Quality (3.46 points): Overall at a "slightly above general" level (**Figure 1**). The high training assessment pass rate (92.8%) lays a foundation for personnel quality, but the low proportion of intermediate and above professional titles (25.1%) and informatized equipment maintenance qualifications (37.9%) restricts the improvement of comprehensive capabilities.

Support Resource Allocation (3.51 points): Rated as "good." The sufficient support funding (95%) provides a strong guarantee, but the aging maintenance equipment and insufficient spare parts reserve at reef stations need to be optimized.

Support Technology Level (3.08 points): At a "general" level. The application rate of advanced diagnostic technology, the coverage rate of informatized management systems, and the independent repair rate of complex faults are all low, and the technical empowerment effect is not obvious.

Support Management Mechanism (3.31 points): The rules and regulations are basically sound, but the evaluation and incentive mechanism lacks scientificity, and the training content is not targeted enough, which affects the release of support efficiency.

Emergency Support Capability (3.40 points): The emergency response time and repair success rate basically meet the requirements, but the low emergency spare parts reserve rate (68%) and weak cross-regional collaborative support capability need to be strengthened.

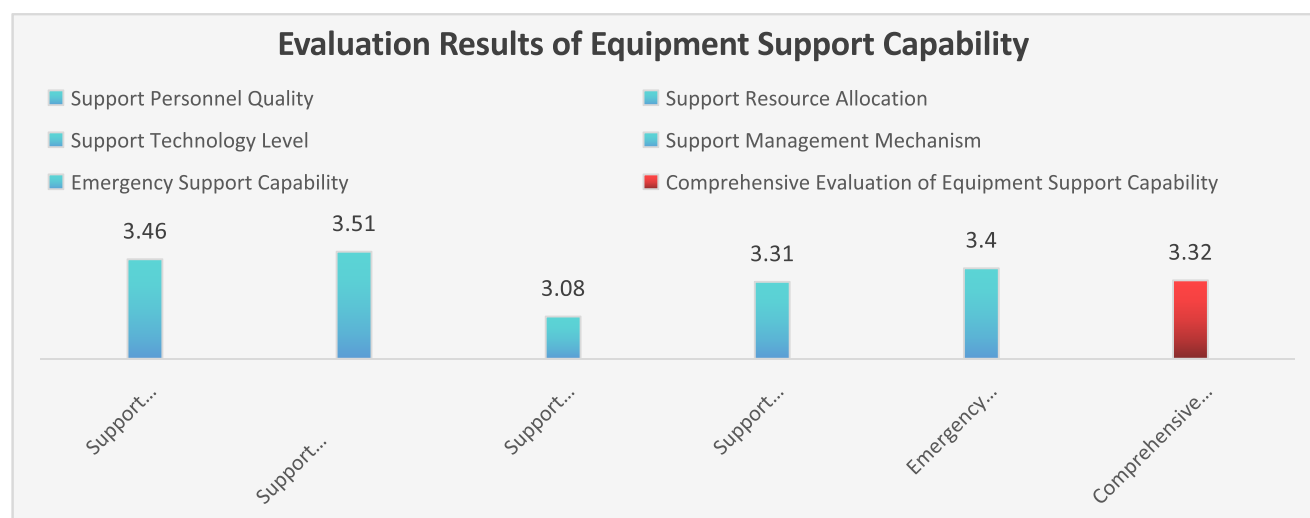


Figure 1. Evaluation results

4.2.2. Test of evaluation results

Expert evaluation method and test-retest reliability method are used to test the evaluation results. Five external experts unanimously believe that the evaluation index system is scientific and reasonable, and the evaluation results are in line with the actual situation of the bureau; the test-retest reliability analysis shows that the correlation coefficient between the two evaluation results after an interval of 1 month is 0.87, indicating that the evaluation results have good stability and reliability.

5. Countermeasures and suggestions for improving the equipment support capability of CCG

5.1. Improve the professional quality of support personnel

Formulate a special talent introduction plan, focusing on recruiting professionals in informatized equipment maintenance and ship power system repair. Cooperate with universities and scientific research institutes to establish talent training bases, and select 30–50 support personnel for practical training every year. Establish a talent echelon management mechanism, give play to the role of technical leaders in mentoring, and strive to increase the proportion of intermediate and above professional titles to more than 35% and the informatized equipment maintenance qualification rate to more than 50% within 3 years.

5.2. Optimize the allocation and management of support resources

Increase investment in reef support stations, update aging maintenance equipment, supplement spare parts reserves, and strive to increase the good rate of maintenance equipment at reef stations to more than 90%; establish a shared management mechanism for support resources to realize resource complementarity between coastal and reef stations; establish a dynamic reserve mechanism for spare parts, and adjust the reserve types and quantities according to the failure rate and task requirements.

5.3. Improve the level of support technology

Introduce advanced technical equipment, such as ship equipment condition monitoring systems and fault diagnosis expert systems, and increase the application rate of advanced diagnostic technology to more than 60%. Accelerate the construction of an informatized management system for equipment support, realize full-process information management of support business, and break information barriers. Strengthen technical cooperation with scientific research institutes, jointly tackle key technical problems such as complex fault repair, and increase the independent repair rate of complex faults to more than 80%.

5.4. Improve the support management mechanism

Revise and improve the equipment support rules and regulations, clarify the work standards and responsibility division of each link, and establish a normalized supervision and inspection mechanism. Build a scientific evaluation and incentive mechanism, directly linking evaluation results with performance appraisal, promotion, rewards, and punishments to mobilize staff enthusiasm. Optimize the training mechanism, carry out demand-oriented training, increase the proportion of practical courses, and organize more than 4 post-training activities every year.

5.5. Strengthen emergency support capability

Revise and improve the emergency support plan, and organize 2–3 emergency drills every year to enhance the response capacity. Establish a special reserve warehouse for emergency spare parts, and increase the reserve rate to more than 85% in accordance with the principle of “sufficient reserve and rapid allocation.” Establish a collaborative support mechanism with surrounding CCG bureaus and local maintenance enterprises to improve the integration efficiency of emergency resources.

6. Conclusion

Combined with the characteristics of the Coast Guard’s equipment support, this paper constructs an equipment support capability evaluation system including 5 criterion layers and 19 index layers, uses the AHP method to determine the index weights, combines the fuzzy comprehensive evaluation method to establish an evaluation model, and conducts empirical research with a certain bureau of the CCG as the object. The evaluation results show that the system can scientifically and objectively reflect the level of the Coast Guard’s equipment support management capability and accurately identify the weak links in management. The research results fill the gap in the scientific management evaluation of the Coast Guard’s equipment support capability, provide an effective tool for the Coast Guard’s equipment support management decision-making and capability improvement, and have strong popularization and application value.

Disclosure statement

The authors declare no conflict of interest.

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The Era Background, Significance, and Key Paths of Accelerating the Development of New-Quality Productivity

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Abstract: Currently, a new round of technological revolution is shaping the new international pattern. Accelerating the development of new-quality productivity is the key to addressing the dilemmas faced by global development, promoting the transformation of productivity, accelerating scientific and technological innovation, advancing high-quality economic development, and driving an overall leap in China's social productivity level. Generally speaking, the proposal of new-quality productivity further enriches and expands Marxist productivity theory; drives the innovation of economic development theories; demonstrates the global significance of Chinese discourse and Chinese theories; provides theoretical and practical guidance for promoting high-quality development; and offers driving support for forging new advantages in international competition. To accelerate the development of new-quality productivity, it is necessary to take scientific and technological innovation as the driver to provide a strong engine for high-quality development; take industrial innovation as the support to stimulate new kinetic energy for industrial carriers in high-quality development; take the innovation of development models as the starting point to highlight the characteristics of high-quality development; take the innovation of institutional mechanisms as the guide to provide institutional guarantees for high-quality development; and take the innovation of talent work mechanisms as the breakthrough to consolidate the talent foundation for high-quality development.

Keywords: New-quality productivity; Era background; Significance; Paths

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1. The era background of developing new-quality productivity

Productivity serves as the foundation and support for the continuous development and progress of humanity, and is the decisive factor driving social development. Different from traditional productivity, new-quality productivity represents a leap forward from traditional productivity in the new context and a new form and manifestation of high-quality development. Its proposal is rooted in profound era and practical backgrounds ^[1].

1.1. The international pattern is evolving rapidly, and global development lacks momentum

At present, the world is undergoing a major transformation unseen in a century at an accelerated pace. The modern technological revolution and industrial revolution have driven more specialized and diversified international division of labor, and scientific and technological innovation has become a key variable affecting and reshaping the world economic landscape. A new round of technological and industrial revolutions has accelerated the improvement of productivity in developed countries, while the cost advantages of developing countries in the global industrial pattern have been gradually weakened. This has prompted all countries to accelerate their efforts to find their positions in global science, technology and industrial development to adapt to changes in the global production structure. In this new round of technological and industrial revolutions, whoever seizes this critical historical opportunity will stand at the forefront of leading global development. At the same time, global development is facing a series of challenges: undercurrents of “de-globalization” are surging, unilateralism and trade protectionism are taking shape at an accelerated pace, and local conflicts occur frequently, leading to a sluggish world economic recovery and a predicament in development. Among these challenges, insufficient production capacity is an important root cause of the global crisis; sluggish economic growth or even worsening situations may particularly exacerbate global risks. To break free from the predicament of global development, it is necessary to promote changes in productivity development and inject new impetus into the development of all countries in the world.

1.2. The competitiveness of traditional productivity is gradually declining, urgently requiring a transition to new forms of productivity

The basic form of traditional productivity mainly relies on the simple aggregation of production factors, driven primarily by factors such as material resources, investment, labor, and land. It features low technological content, labor intensiveness, and repetitive production, often accompanied by problems such as high costs, low efficiency, excessive resource consumption, and severe environmental pollution, which can no longer provide adequate support for sustainable and green development ^[2]. On the other hand, traditional productivity is often associated with the disorderly expansion of traditional production capacity, leading to backward and excess capacity. To effectively respond to various new domestic and foreign challenges, it is urgent to adjust the productivity structure in accordance with the direction and trend of current technological and industrial changes, promote a leap in productivity, accelerate the transformation of productivity from quantitative to qualitative improvement, and achieve a shift from scale expansion to sustainable, coordinated, and high-quality development.

1.3. Scientific and technological innovation has become a key factor driving the development and transformation of productivity

In recent years, with the accelerated advancement of the scientific and technological revolution and industrial economic transformation, cutting-edge technologies led by scientific and technological innovation—such as artificial intelligence, high-end equipment manufacturing, new energy, future manufacturing, future information technology, quantum computing, and biotechnology—have risen rapidly. They have become new engines for world economic growth, driving the transformation and upgrading of traditional industries while fostering the rapid development of new industries, new formats, and new tracks, which have become new growth points of the world economy and the most important growth drivers in the future. The progress and application of these technologies have provided broad development space and markets for the growth of new-quality productivity, giving productivity a different outlook from traditional productivity and laying a foundational support for the

cultivation and development of new-quality productivity^[3].

1.4. The need to achieve economic transformation and upgrading and promote high-quality economic development

On one hand, the world is currently in a period of intensive scientific and technological innovation; disruptive technologies in fields such as new-generation information technology, biology, energy, and materials are emerging on an unprecedented scale. While exerting a profound impact on and transforming the social, economic, and political structures of all countries in the world, they are also reshaping the economic competitiveness of each country. As the largest developing country, China is faced with major historical opportunities and challenges brought by the new round of technological revolution. How to seize this strategic opportunity, fully tap into and release the growth dividends it brings, and gain the initiative in future development will be a crucial factor in realizing Chinese-style modernization. On the other hand, after entering the new development stage, China has fully implemented the new development concept, and its economy is transitioning from high-speed growth to high-quality development, with high-quality development becoming the main theme. The report of the 20th National Congress of the Communist Party of China emphasizes that “high-quality development is the primary task for building a modern socialist country in an all-round way”^[4]. High-quality development cannot rely solely on the input of resources, capital, and labor; its core lies in relying on scientific and technological innovation to drive an exponential leap in productivity, thereby achieving sustainable and high-quality development. In recent years, China has made continuous progress in scientific and technological innovation, and the effectiveness of innovation-driven development has become increasingly evident, placing China in a leading position in the global process of informatization and intelligentization. However, factors restricting high-quality development still exist, requiring new productivity theories to guide high-quality development and promote and support new development practices.

2. The significant theoretical and practical significance of developing new-quality productivity

2.1. New-quality productivity enriches and expands Marxist productivity theory

The theory of productivity is an important foundation of Marxist political economy. Since the reform and opening-up, China has gradually explored and formed the theory of socialist political economy with Chinese characteristics, pointing out that the fundamental task of social development is to liberate and develop productive forces, and putting forward the important assertion that “science and technology is the primary productive force”^[5]. Centering on the main line of liberating and developing social productive forces, new-quality productivity responds to the principal contradictions in current social and economic development, summarizes the achievements of China’s reform practice, focuses on China’s disruptive and cutting-edge technologies, and proposes promoting industrial innovation through scientific and technological innovation to develop new-quality productivity. This enriches and expands Marxist productivity theory, providing a scientific theoretical support for promoting high-quality development.

2.2. New-quality productivity drives the innovation of economic development theories

Traditional economic development theories mainly focus on the role of traditional production factors such as capital, labor, land, and natural resources, holding that economic growth mainly relies on the input of

production factors and total factor productivity. In contrast, new-quality productivity incorporates new factors such as scientific and technological innovation, knowledge accumulation, data resources, and human capital improvement into the economic growth model, endowing the production function and growth model with brand-new connotations. It also emphasizes the optimal combination of various production factors and technological empowerment, making the driving forces of economic growth more diversified and providing a new direction for the transformation of social production methods and production relations.

2.3. New-quality productivity demonstrates the global significance of Chinese discourse and Chinese theories

The proposal of new-quality productivity deconstructs and reorganizes the traditional knowledge system of productivity, adding new conceptual and discourse elements. It features the integration of political nature, academic nature, popularity, and globality, making it easy for the international community to understand and accept ^[6]. It constructs an original iconic concept of Chinese discourse for analyzing China's economic development, innovates the concepts, categories, and expression forms of Chinese discourse, represents the sublimation of productivity-related "Chinese discourse" in the new era, expands China's discourse influence in the global knowledge system of economic development, and demonstrates Chinese wisdom and Chinese strength ^[7].

2.4. New-quality productivity provides theoretical and practical guidance for promoting high-quality development

Currently, achieving high-quality economic development requires maximizing the potential of productive forces to bring about an overall leap in social productivity in the new era. The proposal of new-quality productivity provides theoretical and practical guidance for fully, accurately, and comprehensively implementing the new development concept, accelerating the construction of a modern economic system, advancing high-level scientific and technological self-reliance and self-improvement, and accelerating the construction of a new development pattern, laying a solid foundation for promoting high-quality development.

2.5. New-quality productivity provides driving support for forging new advantages in international competition

In the new round of technological and industrial revolutions, whoever masters key core technologies will hold the initiative in economic development. Faced with the containment, suppression, technological blockade, and decoupling efforts led by Western countries such as the United States, new-quality productivity focuses on scientific and technological innovation—the "key" to shaping national competitiveness. It helps China improve the new nationwide system, fully promote high-level scientific and technological self-reliance and self-improvement, break through key core technologies, strengthen the empowerment of industrial innovation by scientific and technological innovation, and gain strategic initiative and competitive advantages amid the major changes unseen in a century.

3. Key paths to accelerate the development of new-quality productivity

Innovation is the primary driving force for development, a strategic support for building a modern economic system, and the core of developing new-quality productivity. The President of the CPC emphasized that "a prominent feature of new-quality productivity is innovation, which includes not only innovation at the

technological and industrial model levels but also innovation at the management and institutional levels. We must continue to make good efforts in innovation to promote the accelerated development of new-quality productivity”^[8].

3.1. Take scientific and technological innovation as the driver to provide a strong engine for high-quality development

Scientific and technological innovation is the core element of developing new-quality productivity, a key link in opening up new industries, developing new fields, and forging advantages in international competition, and a catalyst for promoting the organic integration of production factors and realizing exponential growth in productivity. To this end, people must accelerate the improvement of China’s scientific and technological innovation capabilities, enhance national core competitiveness, and occupy a high-end position in the global industrial and innovation chains. People should vigorously promote original and basic research, strengthen original innovation oriented towards the frontiers of science, and accumulate original resources and technological reserves for high-quality development. People need to intensify breakthroughs in key core technologies, give full play to the advantages of the new nationwide system, implement key core technology research around national strategies and long-term “bottleneck” issues, and provide key scientific and technological competitiveness for high-quality development. People must strengthen the transformation of scientific and technological achievements, give play to the main role of enterprises in scientific and technological innovation, promote the integrated development of scientific and technological innovation and industrial innovation, and accelerate the transformation of scientific and technological achievements into the actual productivity of enterprises, releasing the supporting role and contribution of scientific and technological innovation^[9].

3.2. Take industrial innovation as the support to stimulate new kinetic energy for industrial carriers in high-quality development

A modern industrial system is an important carrier of a modern economic system and a key symbol of modernization. People must strengthen the guidance of scientific and technological innovation to drive industrial innovation and accelerate the formation of a modern industrial system. Continuously promote the transformation and upgrading of traditional industries: use new technologies, new methods, and new models to upgrade and transform traditional industries, promote their high-end, digital, intelligent, and green development, improve production efficiency, enhance product value, and cultivate new industries, new formats, new advantages, and new growth drivers. Accelerate the layout and expansion of emerging industries: as an important carrier for the in-depth integration of the innovation chain, industrial chain, capital chain, and talent chain, emerging industries should be guided by science and technology, continuously promote the demonstration and application of typical scenarios such as big data, new energy, artificial intelligence, intelligent manufacturing, high-end equipment, and modern medicine, promote the integrated development of the digital economy and the real economy, and optimize and upgrade the economic structure. Layout and build future industries: strengthen forward-looking planning and layout, focus on future leading industries such as future manufacturing, future information, and future materials, create iconic products, open up new tracks, gradually realize industrialization, build a world-leading future industrial cluster, enhance future global competitiveness, and seize the commanding heights of future competition.

3.3. Take the innovation of development models as the starting point to highlight the characteristics of high-quality development

High-quality development requires transforming the production model from an extensive model featuring high

energy consumption, high emissions, and high pollution to a green, low-carbon, sustainable, and eco-friendly model, realizing the economical, intensive, and circular utilization of resources. People should strengthen the optimal combination of green technology and productivity factors, promote the accelerated transformation and application of green and low-carbon technologies, realize industrialization and large-scale application, build green industrial chains and supply chains, establish green manufacturing and service systems, accelerate the formation of a green, low-carbon, and circular economic system, and cultivate truly green and low-carbon new-quality productivity. People need to continuously improve the policy support system for green transformation, develop green financial tools such as green equity financing, green trusts, and green insurance, optimize investment mechanisms, price policies, and market-oriented mechanisms for green development, and ensure the comprehensive green transformation of development^[10]. People should promote the transformation of green and healthy lifestyles, actively advocate green living concepts, cultivate and promote green culture, advocate a simple, moderate, green, and low-carbon lifestyle, establish firm production and living concepts of green development, make green a growth point and support for people's happiness, and promote high-quality economic development through a high-quality ecological environment.

3.4 Take the innovation of institutional mechanisms as the guide to provide institutional guarantees for high-quality development

People must continue to deepen reforms, strengthen guidance and policy support for the development of new-quality productivity, eliminate institutional drawbacks incompatible with its development, establish a policy system adapting to the development of new-type productivity, strengthen the reform, coordination, and management of the market and scientific and technological systems, increase policy support for the new nationwide system, national strategic scientific and technological forces, and future strategic fields, smooth the optimal combination and flow of various production factors, and provide strong policy support for the development of new-quality productivity. Focusing on the development of new-quality productivity, people should establish and improve relevant assessment, incentive, and evaluation systems to guide local governments, markets, enterprises, and industries to increase investment in scientific and technological innovation and better promote high-quality economic development. People need to continue to implement the opening-up strategy, formulate a global development strategy for new-quality productivity, optimize the layout to absorb global advanced productivity factors, strengthen productivity cooperation and sharing, and guide and promote the accelerated formation of global new-quality productivity.

3.5. Take the innovation of talent work mechanisms as the breakthrough to consolidate the talent foundation for high-quality development

People should promote the integrated reform of the education, science and technology, and talent systems, implement the strategies of rejuvenating the country through science and education, strengthening the country through talent, and driving development through innovation, promote a virtuous cycle of education, science and technology, and talent, realize the complementary advantages of education, science and technology, and talent, and achieve a “synergistic multiplier effect.” People should give full play to the leading role of higher education, promote comprehensive reforms in higher education, strengthen organized scientific research in accordance with national strategies and technological development trends, optimize discipline settings and talent training models, and provide talent and technological support for the development of new-quality productivity. Centering on the high-quality factors of new-quality productivity, people should cultivate high-quality talents in various fields, focus on cultivating top scientific and technological innovation talents, skilled talents, industrial talents, and

management talents, and promote the more efficient development of new-quality productivity. People need to deepen the reform of talent evaluation, establish and improve a talent evaluation system centered on scientific and technological innovation and substantive contributions, encourage innovative talents, and promote the sustainable development of new-quality productivity.

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The Impact of Peer Relationships on the Mental Health of Students with Social Adaptation Disorders

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Abstract: With the continuous expansion of higher vocational education, students in vocational colleges face clear changes in learning methods, living environments, and interpersonal communication. Because of this, problems of social adaptation have become more obvious. Social Adaptation Disorders not only affect students' learning involvement and interpersonal development, but also have a long-term influence on their mental health. Among vocational college students, peer relationships are one of the most important sources of social support in daily life. They play an important role in reducing social adaptation pressure, adjusting emotional experience, and promoting mental health. Based on this background, this study takes vocational college students as the research group. After reviewing theories related to Social Adaptation Disorders, peer relationships, and mental health, this study builds a theoretical framework to explain how peer relationships affect the mental health of students with Social Adaptation Disorders. Empirical methods are used to test the research hypotheses. The results show that peer support and peer acceptance have a clear positive effect on the mental health of these students, while negative peer interactions may increase their psychological stress. These findings help people better understand the relationship between social adaptation and mental health among vocational college students. They also provide a theoretical basis for mental health education and intervention programs in vocational colleges that focus on peer relationships.

Keywords: Vocational college students; Social Adaptation Disorders; Peer relationships; Mental health; Theoretical framework

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1. Introduction

With the rapid development of higher vocational education in China, the number of students in vocational colleges has increased steadily. At the same time, problems related to students' psychological development and social adaptation have attracted growing attention from educators and researchers. Compared with undergraduate

students, vocational college students often face more complex situations in academic orientation, social expectations, and future career planning. Some students have clear difficulties in role identity, interpersonal communication, and adapting to new environments. If these Social Adaptation Disorders are not identified and addressed in time, they may lead to anxiety, depression, and low self-confidence. These problems can further affect students' learning performance, career development, and overall mental health. Therefore, it is necessary to examine the factors related to Social Adaptation Disorders and their impact on mental health among vocational college students. Interpersonal relationships play an important role in students' socialization and psychological development. Among them, peer relationships are the most direct and frequent form of social interaction for young people. Peer relationships influence students' emotional experience and self-evaluation, and they are also closely related to the development of social adaptation ability. Positive peer support and peer acceptance can provide emotional comfort and practical examples of social behavior. This helps students reduce adaptation pressure and strengthen their sense of belonging, which is beneficial to mental health. In contrast, distant, rejecting, or conflict-based peer relationships may increase feelings of loneliness and psychological stress, especially for students with Social Adaptation Disorders. Many previous studies have explored students' social adaptation and mental health from perspectives such as family background, individual personality, or school management. However, peer relationships have received less attention, and research focusing specifically on vocational college students remains limited. In particular, the way peer relationships influence mental health under conditions of Social Adaptation Disorders is still not clearly explained. Based on this gap, the present study focuses on vocational college students and examines Social Adaptation Disorders from the perspective of peer relationships. A theoretical framework is developed and tested through empirical analysis. This study aims to deepen the understanding of vocational college students' mental health and to provide practical references for peer-based mental health education and intervention.

2. Concept definition and theoretical background

2.1. Concepts of social adaptation disorders and mental health of vocational college students

Social Adaptation Disorders refer to long-term problems that individuals show in behavior, emotion, or thinking when they face changes in the environment or new social role demands. These difficulties usually appear because their coping ability is not strong enough. From a psychological perspective, Social Adaptation Disorders are not a single symptom. Instead, they reflect a mixed state of poor adaptation. Such difficulties are often shown in problems with building stable and effective interaction patterns in learning, daily life, and interpersonal communication. Among vocational college students, Social Adaptation Disorders are closely linked to educational background, academic pressure, and social expectations. After entering college, students must quickly adjust to practice-oriented teaching and career-focused learning environments. Without enough psychological preparation or support, some students may show low learning engagement, unclear goals, and weak self-efficacy, which lowers their overall adaptation level^[1]. At the learning level, students with Social Adaptation Disorders often have low motivation, limited classroom participation, and weak recognition of their major. At the interpersonal level, they may avoid social interaction, lack communication skills, or be overly sensitive to peer evaluation. This makes it difficult for them to build stable and supportive peer relationships. At the emotional level, they may experience anxiety, depression, irritability, or strong mood changes. When facing academic and life pressure, they often

lack effective ways to manage emotions. These problems are closely connected and together increase the risk to students' mental health. Mental health is generally understood as a balanced and stable state of cognition, emotion, and behavior. It includes not only the absence of mental problems but also the presence of positive psychological functioning. In this study, mental health is defined through emotional state, self-identity, interpersonal adaptation, and psychological resilience. Considering these dimensions together helps provide a clearer understanding of the mental health of vocational college students with Social Adaptation Disorders and the mechanisms behind it ^[2].

2.2. Theoretical foundations related to peer relationships

Peer relationships are an important part of the socialization process and play a basic role in psychological development and social adaptation during youth. Many theories suggest that peers are not only partners for emotional communication and social learning, but also key sources of social support and self-identity ^[3]. Social support theory helps explain the psychological value of peer relationships. It points out that when individuals face pressure or challenges, emotional, informational, and practical support from others can reduce the negative impact of stress on mental health. For vocational college students, peer support is often more direct and frequent than family support. Positive peer relationships can increase feelings of safety and belonging and help reduce social adaptation pressure, which protects mental health. Developmental contextual theory further emphasizes that individual development always occurs within specific social environments. Peer groups are one of the closest and most influential environments for young students. According to this theory, behavior and psychological states are shaped through continuous interaction with peers rather than developing in isolation. In vocational colleges, where students study and live in relatively closed and highly interactive settings, peer relationships have a long-term influence on social adaptation and mental health through learning cooperation, emotional exchange, and shared values. For students with Social Adaptation Disorders, positive peer environments support learning social rules, improving communication skills, and gradually strengthening adaptation. In contrast, negative peer environments may increase avoidance behavior and negative self-perception ^[4]. Interpersonal interaction theory focuses on the interaction process itself and highlights the dynamic and two-way nature of psychological development. Peer relationships are constantly adjusted through interaction. Feedback from peers directly affects students' self-evaluation, emotions, and behavior choices. Acceptance and positive feedback support healthy development, while frequent conflict or rejection can increase stress and weaken social adaptation. Together, these theories provide a clear basis for understanding how peer relationships influence the mental health of students with Social Adaptation Disorders ^[5].

3. Theoretical framework and research hypotheses

3.1. Construction of the theoretical model on the impact of peer relationships on the mental health of students with Social Adaptation Disorders

Based on social support theory, developmental contextual theory, and interpersonal interaction theory, peer relationships can be understood as a key link between the social environment and individual psychological states. On this basis, this study builds a theoretical model to explain how peer relationships influence the mental health of students with Social Adaptation Disorders. In the model, peer relationship quality is treated as the main influencing factor, mental health is the outcome, and social adaptation status plays a mediating role. The model emphasizes that these factors are closely connected and interact with each other ^[6]. For vocational college students with Social Adaptation Disorders, mental health problems do not come from a single cause. Instead, they develop

gradually through the combined effects of peer interaction, adaptation ability, and emotional regulation. Good peer relationships can influence mental health in two main ways. First, they have a direct effect through social support. Emotional care, understanding, and acceptance from peers can reduce stress in study and daily life and lower feelings of anxiety and loneliness. Second, peer relationships also have an indirect effect by improving social adaptation. Positive peer interactions help students learn social behaviors, build communication confidence, and adapt better to their environment. Over time, this supports healthier emotional management and learning participation. Peer relationships include different aspects, such as peer support, peer acceptance, and interaction quality. Supportive relationships help reduce negative emotions, while conflict and rejection may increase stress and harm mental health. This model offers a clear framework for later hypothesis testing and empirical analysis ^[7].

3.2. Research hypotheses

Based on the theoretical analysis and model discussed above, different dimensions of peer relationships play different roles in the mental health of students with Social Adaptation Disorders. Peer support, peer acceptance, and peer conflict are key factors that reflect the overall quality of peer relationships. These factors influence students' emotional experience, self-identity, and social adaptation in both direct and indirect ways. From the perspective of social support theory, stable and positive peer support can provide emotional comfort and practical help. It helps students reduce stress and frustration in learning and daily life. As a result, students feel more emotionally stable and show better mental health. Therefore, this study suggests that higher levels of peer support are associated with better mental health among vocational college students with Social Adaptation Disorders. Peer acceptance refers to how much students feel recognized and accepted by their peer group. It strongly affects their sense of belonging and self-worth. For students with Social Adaptation Disorders, peer acceptance can reduce tension and avoidance in social situations ^[8]. It can also increase their willingness to take part in group activities and improve their confidence in adapting to social environments. For this reason, peer acceptance is expected to have a positive relationship with mental health. In contrast, peer conflict reflects negative peer experiences such as rejection and frequent interpersonal friction. According to interpersonal interaction theory, repeated peer conflict can increase negative emotions and harmful self-evaluation. This weakens social adaptation ability and harms mental health. Overall, this study proposes that peer support and peer acceptance have positive effects on mental health, while peer conflict has a negative effect. These hypotheses guide the later empirical analysis and help test the theoretical model ^[9].

4. Research design and methods

4.1. Research participants and sample selection

This study takes vocational college students who are currently enrolled as the research participants. Several representative vocational colleges were selected as the sample sources. Students from different majors and grade levels were included to make sure the sample structure is diverse, and the research results can be applied more broadly. The participants mainly came from several vocational colleges in the same region. Questionnaires were distributed using class-based cluster sampling. During the research process, voluntary participation and anonymous responses were strictly followed. After the questionnaires were collected, the data were checked and organized. Invalid or incomplete responses were removed, and valid data were kept for later analysis. In terms of sample size, this study tried to include as many participants as possible while still meeting the needs of statistical

analysis. This was done to improve the stability and reliability of the results. A pilot survey and a formal survey were carried out step by step to make sure the final sample size was large enough for correlation analysis and model testing. At the same time, attention was paid to the balance of gender, grade level, and major^[10]. This helps the sample better reflect the general characteristics of vocational college students. Students with Social Adaptation Disorders were identified mainly through standardized measurement tools. A social adaptation scale was used to assess all participants first. Based on the scale scores, clear criteria were set. Students whose social adaptation level was much lower than the norm or who fell into the low-score range were identified as students with Social Adaptation Disorders. This method helps keep the screening process objective and scientific. It also makes it possible to accurately identify students with Social Adaptation Disorders from the whole sample, which provides a solid database for later analysis of the impact of peer relationships on mental health.

4.2. Research instruments and data collection

To fully examine the impact of peer relationships on the mental health of vocational college students with Social Adaptation Disorders, this study used standardized psychological measurement tools to assess social adaptation, peer relationship quality, and mental health level. Social adaptation was measured using a well-established social adaptation scale. This scale evaluates students' adaptation in learning, interpersonal, and emotional dimensions. It has good reliability and validity and can accurately reflect students' adaptation status during college life. The results of this scale provide reliable support for identifying students with Social Adaptation Disorders and analyzing their adaptation characteristics. Peer relationships were measured using a peer relationship scale. This scale mainly includes peer support, peer acceptance, and peer conflict. It reflects students' overall experiences in peer interactions. The scale shows both positive aspects, such as emotional support and acceptance, and negative aspects, such as interpersonal conflict and rejection. This makes it possible to analyze how different dimensions of peer relationships influence mental health in different ways. Mental health was measured using a psychological health scale designed for college students. This scale assesses mental health from aspects such as emotional state, self-identity, and psychological adaptation. It can effectively show how students react psychologically when facing pressure from study and daily life. During data collection, questionnaires were distributed in a centralized way. Before filling out the questionnaire, participants were informed about the research purpose and instructions. Their informed consent and anonymity were clearly ensured. After the questionnaires were collected, the data were coded and organized in a unified manner. This provided reliable data for later statistical analysis and model testing.

5. Research results and analysis

5.1. Descriptive statistics and correlation analysis results

After data cleaning and screening, descriptive statistical analysis was carried out on the main variables to understand the general situation of vocational college students with Social Adaptation Disorders. The results show that the average levels of peer support and peer acceptance are moderate. This suggests that many students can receive some emotional support and recognition from peers, but this support is not always stable or strong. At the same time, a part of the sample shows relatively high levels of peer conflict, which indicates that these students are more likely to experience disagreement and negative interaction in peer communication. Regarding mental health indicators, the results reflect noticeable emotional fluctuation and adaptation pressure, showing clear differences in mental health conditions among students with Social Adaptation Disorders. Based on the descriptive results,

correlation analysis was further used to examine the relationships between peer relationship dimensions and mental health. The analysis shows that peer support is positively related to mental health. Students who receive more peer support tend to have better emotional states and stronger psychological adaptation. Peer acceptance also shows a significant positive relationship with mental health, which means that feeling accepted by peers helps students maintain emotional stability and positive psychological experience. In contrast, peer conflict is negatively related to mental health. Frequent conflict and negative peer interactions are associated with higher psychological stress and lower mental health levels. Overall, these results provide initial empirical evidence that peer relationships are closely linked to the mental health of vocational college students with Social Adaptation Disorders. They also support the theoretical model and research assumptions of this study.

5.2. Analysis of the impact of peer relationships on mental health

Based on the correlation results, further empirical analysis was conducted to examine how different aspects of peer relationships affect the mental health of vocational college students with Social Adaptation Disorders. The results show clear differences in both direction and strength among these effects. This suggests that peer relationships influence mental health through multiple pathways rather than a single mechanism. Peer support shows a strong positive effect on mental health, which is consistent with the research hypothesis. Students who receive higher levels of peer support tend to show better emotional states, stronger self-identity, and improved psychological adaptation. This indicates that care, understanding, and practical help from peers in daily life can reduce psychological pressure. Peer support also provides important resources for emotional adjustment and stress coping, which helps protect mental health. Peer acceptance also has a significant positive influence on mental health. Students who feel more accepted by their peers generally report better mental health outcomes. Peer acceptance strengthens feelings of belonging and social identity, reduces negative self-evaluation and interpersonal anxiety, and encourages active social participation. For students with Social Adaptation Disorders, peer acceptance is not only a form of external support but also a key foundation for rebuilding confidence and improving social adaptation. In contrast, peer conflict has a clear negative effect on mental health. Frequent conflicts and negative peer interactions increase emotional distress and weaken students' ability to manage stress. Overall, the findings support the theoretical model of this study and highlight the important role of peer relationships in mental health development.

6. Discussion and implications

6.1. Theoretical interpretation of the research results

This study uses empirical analysis to explore how peer relationships influence the mental health of vocational college students with Social Adaptation Disorders. Overall, the findings support the proposed theoretical model and provide practical evidence for applying related theories to this group. From the perspective of social support theory, the positive effect of peer support shows that peers are one of the most direct and important sources of help in students' daily lives. Peer support can reduce the emotional and behavioral stress caused by Social Adaptation Disorders. For students with weaker adaptation ability, care, encouragement, and assistance from peers help lower psychological pressure, improve emotional stability, and increase feelings of safety, which supports better mental health. Developmental contextual theory also helps explain the results. Vocational college students live and study in relatively stable peer environments for long periods. These peer contexts continuously shape their

social adaptation and psychological states. Positive peer acceptance creates a supportive interaction environment, helping students learn social rules, improve communication skills, and build more positive self-understanding. In contrast, peer conflict may strengthen avoidance behavior and negative thinking, making adaptation problems more serious. The different effects of peer acceptance and peer conflict reflect the long-term influence of peer contexts. Interpersonal interaction theory further explains how feedback from peers affects emotions and self-evaluation. Positive feedback supports emotional stability, while rejection and conflict increase negative emotions. Together, these theories confirm the key role of peer relationships in shaping mental health among students with Social Adaptation Disorders.

6.2. Practical implications for mental health education in vocational colleges

Based on the empirical findings of this study, vocational colleges should place more emphasis on the positive role of peer relationships when carrying out mental health education, especially for students with Social Adaptation Disorders. Peer relationships should be included as an important part of the overall mental health education system. First, in terms of building peer support systems, vocational colleges can create stable peer support networks through organized methods, such as learning support groups, interest-based clubs, and class cooperation projects. These activities provide more chances for positive interaction among students. By strengthening emotional connections and practical support between peers, students with Social Adaptation Disorders can receive continuous psychological support in daily study and life, which helps reduce adaptation pressure. Second, at the level of peer counseling, vocational colleges can train student volunteers under the guidance of professional counselors or psychology teachers. These students should have basic psychological knowledge and communication skills, and can take part in peer counseling and support activities. Compared with traditional teacher–student counseling, peer counseling can more easily reduce psychological resistance among students with Social Adaptation Disorders. It can also increase trust and willingness to express feelings. Through equal communication and experience sharing among peers, students can better recognize and manage negative emotions, improve social adaptation ability, and enhance mental health. In addition, vocational colleges should pay attention to creating a positive class interpersonal atmosphere. Schools can encourage inclusive, supportive, and diversity-respecting class cultures through theme-based class meetings, team training, and cooperative learning activities. These activities help students develop empathy and cooperation awareness, and reduce peer conflict and exclusion. A healthy interpersonal atmosphere not only improves overall class cohesion but also provides a safe and stable psychological environment for students with Social Adaptation Disorders. In general, integrating peer support concepts into mental health education practices in vocational colleges can help form multi-level and sustainable intervention mechanisms. This approach is more effective in promoting the mental health development of students with Social Adaptation Disorders.

7. Conclusion

This study focuses on vocational college students with Social Adaptation Disorders and systematically explores the impact of peer relationships on their mental health. The results show that peer relationships play an important role in mental health development. Peer support and peer acceptance have clear positive effects on mental health, while peer conflict has a negative effect. Good peer relationships help reduce adaptation pressure, improve emotional stability, and strengthen a sense of social belonging, which leads to better overall mental health. Based

on these findings, this study suggests that mental health education in vocational colleges should fully recognize the positive function of peer relationships. By improving peer support systems and creating positive interpersonal environments, schools can better support the healthy development of students with Social Adaptation Disorders.

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Research on the Activation Pathways of Dormant Resources in the Guangdong-Hong Kong-Macao Greater Bay Area Under the Guidance of the “Project of Promoting High-quality Development in 100 Counties, 1,000 Towns and 10,000 Villages”

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Abstract: Under the background of the “hundred million project” in Guangdong Province, the activation of sleeping resources in the Guangdong-Hong Kong-Macao Bay area has become an important issue to promote regional coordinated development. This paper sorts out the current situation and activation practice of Dawan district’s sleeping resources such as culture, human resources, land and industry, and analyzes the current challenges such as talent shortage, weak cultural heritage, and lack of infrastructure, combined with typical cases such as Tangjiawan in Zhuhai, Dongfeng in Zhongshan, and Huidong in Huizhou, and then puts forward the activation paths such as the talent strategy of “combining education with introduction”, “intangible cultural heritage+tourism” integration path, infrastructure optimization, and industrial collaborative innovation. The research shows that the value transformation of sleeping resources can be realized through the coordination of multiple subjects and mechanism innovation, which provides a reference for the high-quality development and Rural Revitalization of the Guangdong-Hong Kong-Macao Greater Bay area.

Keywords: Dormant resources; Guangdong-Hong Kong-Macao Greater Bay Area; The “Project of Promoting High-quality Development in 100 Counties, 1,000 Towns and 10,000 Villages”; Ecological products; Value realization

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1. Introduction

As China’s economic and social development has entered a new stage, the imbalance between urban and rural

regional development in Guangdong has become increasingly prominent, and the development gap between the Pearl River Delta and Northern and western Guangdong is still large. In order to solve this problem and promote the high-quality development of the province, the Guangdong provincial government comprehensively promoted the implementation of the “million project” in 2023. In this context, revitalizing the “sleeping resources” — that is, the resources such as land, culture, ecology, human resources, industry, and data that have not been fully exploited and utilized — has become an important measure to promote the “million project.” The two promote each other and jointly inject power into the coordinated development of the region ^[1]. At present, around the “hundred million project” and rural revitalization, the academic community has carried out many beneficial explorations, such as Diao and Wu, taking Shaxinlang village, Guangning County, Zhaoqing City as an example to summarize the experience of rural high-quality development ^[2]; Deng and Chen discussed how rural e-commerce and agricultural automation can help the “million project” ^[3]; Qiu and others analyzed the role of talents in promoting regional development from the perspective of high-end youth talent exchange ^[4]. However, most of the existing studies focus on specific regions or single resource types, and there is still a lack of integrated discussion on how to systematically identify and activate multiple sleeping resources in the Guangdong-Hong Kong-Macao Greater Bay area under the guidance of the “million project.” Therefore, based on the existing research, this paper aims to focus on Guangdong-Hong Kong-Macao Dawan District, sort out the current situation and activation practice of its sleeping resources such as culture, manpower, land and industry, analyze the challenges, and then put forward the resource activation path with regional characteristics, in order to provide reference for deepening the implementation of the “hundred million project” and promoting the coordinated development and Rural Revitalization of Dawan district.

2. Overview of sleeping resources in the Guangdong-Hong Kong-Macao Great Bay area

2.1. Overview of cultural sleeping resources

The cultural sleeping resources in the Guangdong-Hong Kong-Macao Bay area mainly refer to the physical and intangible cultural heritage that has not been systematically sorted out, effectively protected, and innovatively utilized in the region. Specifically, it includes a large number of historical buildings, traditional villages, agricultural cultural heritage, folk festivals, local skills, and public cultural facilities scattered in villages and towns. These resources are often idle or inefficient due to a lack of overall planning, insufficient capital investment, an imperfect inheritance mechanism, or a poor connection with modern life. Its “sleeping” features are mainly as follows: the physical space is abandoned, or the function is shrinking, the cultural memory and skills are facing the inheritance fault, and the cultural value has not been effectively transformed into social and economic value. At present, although some places have begun to pay attention to the protection and utilization of cultural resources, as shown in Sun Lin’s research on Jingmei village in Xinhui, Jiangmen, the village can revitalize the countryside by mining intangible cultural heritage, Dawan district as a whole still faces problems such as unclear cultural resources, single activation mode, and insufficient regional linkage, and its profound cultural heritage has not been fully released ^[5].

2.2. Overview of human sleeping resources

The “sleeping” of human resources in the Guangdong-Hong Kong-Macao Greater Bay area is mainly manifested by structural imbalance and unexplained potential. On the one hand, rural areas are facing brain drain, the left

behind population is aging, the skills are single, and the potential of a large number of local labor forces has not been tapped; On the other hand, there are also some professional talents in cities whose skills do not match the job demand, or who fail to fully participate in regional innovation cooperation. This “sleeping” state restricts the upgrading of rural industries and the innovation and development of enterprises. Existing studies have focused on the reshaping of human resource management by digital and green transformation. For example, Liyuwei discussed the empowerment of digital and intelligent transformation on enterprise human resources, and Yang Min analyzed the significance of green human resource management on the revitalization of rural culture ^[6-7]. These studies point to a new direction of human resource development. However, Dawan district still has mechanism barriers in terms of cross-regional talent flow, rural talent training, and skills upgrading, resulting in a large number of human resources failing to give full play to their effectiveness in the “hundred million project.”

2.3. Overview of land sleeping resources

Land sleeping resources mainly refer to idle and inefficient construction land and agricultural land in the Greater Bay area of Guangdong, Hong Kong, and Macao, especially in the peripheral rural areas and some urban fringe areas. Specifically, it includes idle rural homesteads, abandoned land for rural enterprises, storage land with a low utilization rate, and development land temporarily shelved due to planning adjustments. These land resources have not been intensively utilized, or their functions have not been improved, which not only causes a waste of space resources, but also limits the development of rural industries and the growth of farmers’ property income. At present, the reform of the “separation of three rights” of rural residential land has provided a policy basis for land circulation and revitalization. However, in the actual implementation, there are still many problems, such as the poor transfer of property rights, the imperfect market-oriented allocation mechanism, and the difficulty of planning integration. As a result, a large number of land resources have been in a “sleep” state for a long time, which has failed to effectively support urban-rural integration and regional high-quality development.

2.4. Overview of industrial sleeping resources

Industrial sleeping resources mainly refer to those industrial elements that have fallen into recession or stagnation due to failing to adapt to the development requirements of the new era within the Guangdong-Hong Kong-Macao Greater Bay area, especially in traditional industrial agglomeration areas and rural areas. Including the factory facilities left by the transformed or relocated industries, the traditional processes and products with market potential but backward technology, the local characteristic agricultural resources that fail to integrate into the modern industrial chain, and the industrial links that fail to give full play to their advantages due to the homogenization of regional competition. Although the industrial system of Dawan district is developed as a whole, under the pattern of significant internal differences, the industrial resources of some regions are not effectively connected with the overall innovation chain and value chain of the bay area. Especially under the development concept of “green water and green mountains are golden mountains and silver mountains” and the requirements of green transformation, many traditional industrial resources are facing the pressure of transformation and upgrading. If their potential economic and ecological values cannot be reactivated through the innovation path, they will continue to be in a “sleeping” state, restricting the coordinated development and comprehensive revitalization of the region.

3. Current situation of the practice of activating sleeping resources in the Guangdong-Hong Kong-Macao Great Bay area

3.1. Main ways to activate sleeping resources

The Guangdong-Hong Kong-Macao Great Bay area has formed a diversified practice path in the activation of sleeping resources. Integrated development of culture and tourism is a common way. By excavating local characteristic culture and combining it with the tourism industry, people can achieve win-win economic and cultural benefits. Technology empowerment and digital transformation are increasingly critical. People should use big data, the Internet of things and other technologies to revitalize data resources and promote the upgrading of traditional industries. Policy guidance and market-oriented cooperation also play an important role. The government attracts social capital to participate in the development of idle resources through incentive policies, which improve the efficiency and flexibility of resource allocation. In general, the practice of the Dawan district shows the composite characteristics of “government guidance, market operation, multi-party participation, and technology drive”, which provides diversified tools for resource activation.

3.2. Typical cases of activation of sleeping resources

3.2.1. Activation case of industrial resources in Tangjiawan Town, Zhuhai City, Guangdong Province

Tangjiawan town has transformed the Tangjia second industrial zone with scattered rights and interests and disorderly forms into “Gangwan No. 1” science and technology park through government-led and state-owned enterprise operation. The project integrates resources through collective land transfer, debt restructuring, and other ways, successfully introduces more than 50 high-tech enterprises, and actively participates in the Hong Kong-Macao talent cooperation plan, realizing the leap from inefficient industrial zones to innovative industrial parks, and becoming an example of industrial resource activation under the “million project”^[8].

3.2.2. Activation case of cultural resources in Dongfeng Town, Zhongshan, Guangdong

Dongxing community in Dongfeng Town, relying on the Shakou ferry with a history of more than 70 years, is activated through the collaborative mode of “party building+social forces.” The community Party committee mobilized the local people and attracted the love enterprise Zhongjing company to invest in the construction of Gudu cultural Pavilion and other facilities. The idle space was built into a riverside landscape belt rich in historical memory, realizing the organic combination of cultural memory preservation, community environment improvement, and local cultural and tourism development.

3.2.3. Activation cases of ecological resources in the Huidong area, Huizhou, Guangdong

Huidong County systematically activates mangrove ecological resources through the three-step path of “protection and restoration — innovation and exploration — ecological realization.” Since 2013, mangrove planting and restoration have been carried out continuously, and the “mangrove planting aquaculture coupling” mode has been explored. After 2021, through the transfer of mangrove carbon sequestration development rights, the value of ecological products has been realized successfully, forming a compound development mode of “mangrove restoration+biodiversity protection+ecotourism+carbon sequestration trading”, which provides the first experience for the marketization of ecological resources.

4. Challenges faced by the activation of sleeping resources in the Guangdong-Hong Kong-Macao Great Bay area

4.1. Talent shortage challenge

Talent shortage is the key bottleneck restricting the activation of sleeping resources in the Dawan district. Rural areas are generally faced with a shortage of professional and technical personnel, operation management talents, and high-quality digital talents, which directly affects the planning, implementation, and innovation efficiency of resource revitalization. Although it has become a consensus to cultivate and introduce talents, in the specific implementation, there are still difficulties, such as the talent sinking mechanism is not smooth, the localization training system is not perfect, and the incentive guarantee is insufficient, resulting in a gap between the talent supply and the actual demand for Rural Revitalization ^[9].

4.2. Cultural inheritance challenges

The activation of cultural resources faces the dual pressure of inheritance and development. On the one hand, the unbalanced development of urban and rural areas and the outflow of population lead to many intangible cultural heritage skills and rural cultural memory facing the inheritance fault crisis; On the other hand, part of the traditional culture has a single form of expression, which is not effectively combined with contemporary aesthetics, market demand and technical means, resulting in its Limited dissemination and influence, and it is difficult to achieve sustainable activation and utilization, so the economic and social value of cultural resources cannot be fully released.

4.3. Infrastructure challenges

The imbalance of infrastructure is the physical constraint of resource activation. Especially in the peripheral rural areas of the bay area, there are still shortcomings in the transportation network, logistics system, information network, environmental protection facilities, etc., which affect the smooth circulation of resource elements, the extension and connection of the industrial chain, and the application of digital activation means. The lag of infrastructure not only reduces the efficiency of resource allocation, but also restricts the linkage development between urban and rural areas, which has become a problem that needs to be solved continuously in the promotion of “millions of projects.”

5. Innovation path for activating sleeping resources in the Guangdong-Hong Kong-Macao Greater Bay area

5.1. Dual wheel drive to alleviate talent shortage

In view of the talent shortage, it is necessary to build a long-term mechanism combining “internal cultivation” with “external introduction.” In terms of internal cultivation, people should optimize the vocational education and skill training system, deepen the cooperation between schools and enterprises, and integrate production and education, and pay attention to the cultivation of high-quality application-oriented talents with localization and digitization. In terms of external introduction, it is necessary to improve the talent evaluation and incentive mechanism, build a talent cooperation platform between Guangdong, Hong Kong, and Macao, attract high-end professionals and management teams to participate in rural construction, and form a benign ecology of talent convergence and growth.

5.2. Integration path of “intangible cultural heritage” and tourism

Promoting the deep integration of “intangible cultural heritage+” and tourism is an effective way to activate cultural resources. Under the principle of protection priority, cultural and tourism enterprises can be supported to develop intangible cultural heritage experiences, cultural and creative products, and other formats by setting up special support funds and encouraging social capital participation. At the same time, people should actively use new media technologies such as short videos and digital exhibitions to broaden communication channels, and learn from Macao’s “intangible cultural heritage zero distance workshop” and other modes to enhance the sense of public participation and realize the benign interaction between cultural protection and inheritance and tourism economic development ^[10].

5.3. Improve the innovation path of infrastructure

Infrastructure improvement should focus on systematic improvement and intelligent transformation. In terms of transportation, people need to accelerate the integration of regional transportation, optimize the connection of urban and rural road networks, and improve logistics efficiency. In terms of digital infrastructure, people should expand high-speed network coverage and build a smart rural platform. In addition, it is possible to explore the establishment of a “major scientific and technological infrastructure research and development project in Dawan district” to attract multiple inputs, break through capital and technological constraints, and provide solid hardware support and technological empowerment for resource activation.

5.4. Innovation path of industrial resource activation

Industrial resource activation focuses on promoting the transformation and upgrading of traditional industries and the cultivation of emerging formats. On the one hand, the added value of traditional industries can be improved through green technology transformation and design empowerment; On the other hand, people should actively build a cross-regional industrial coordination mechanism and guide social capital to invest in scientific and technological innovation and achievement transformation. For example, in the field of characteristic industries such as medical devices, people can increase policy support and service quality, strengthen quality supervision and brand building, so as to activate the industrial potential and enhance the overall competitiveness.

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Research on the Pathways to Fostering a Sense of Community for the Chinese Nation in the New Media Era

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Abstract: New media have profoundly reshaped the context for disseminating innovative theories. This paper aims to elucidate that the rapid development of digital media presents both significant opportunities and formidable challenges for fostering a strong sense of community for the Chinese nation. In response to these dual aspects, this study systematically analyzes the core mechanisms and practical possibilities of how digital media can contribute to this goal from three dimensions: top-level design, civic literacy, and platform responsibility.

Keywords: New media; A sense of community for the Chinese nation; Digital communication; Technological ethics

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1. Introduction

The General Secretary emphasized that “the internet is the primary platform and top priority for ideological propaganda work, and it should become the greatest increment in forging a strong sense of community for the Chinese nation”^[1]. New media represent the primary manifestation of the internet. In this context, leveraging new media to optimize the publicity and education of the Chinese national community consciousness has become an inevitable and trend-aligned choice for disseminating innovative theories.

New media primarily refers to interactive and convergent media forms and platforms based on digital technology, network technology, other modern information technologies, or communication technologies. This includes communication mediums such as the internet—often termed the fourth media—and mobile networks, referred to as the fifth media^[2]. New media have not only reshaped social interaction patterns but have also provided a new arena and brought fresh opportunities for the dissemination of innovative theories. However, it also introduces new challenges. While the academic community has taken note of this research area, studies on the operational mechanisms and relevant pathways of new media remain somewhat insufficient. This article focuses

on the communication mechanisms of new media platforms, addresses the novel issues faced in the dissemination of innovative theories in the new media era, and seeks to identify corresponding solutions to overcome these challenges.

2. The new media era: The digital communication background of a sense of community for the Chinese nation

The media and public affairs are increasingly intertwined, becoming the most fundamental provider of ideas^[3]. The promotion and education of the Chinese national community consciousness in the era of traditional media mainly rely on the offline domain and linear textual narrative. Its coverage is limited by both physical space and fixed forms, making it particularly unattractive to the younger generation growing up with digital technology. In terms of communication effectiveness, the one-way transmission mode leads to information presentation being contextualized, lagging, and lacking in interaction, making it difficult to transform abstract theories into tangible experiences. The audience is prone to alienation, which restricts the deep construction of identity.

In the era of intelligent media, leveraging technologies such as virtual reality and immersive audio has given rise to a new paradigm characterized by immersive and interactive communication, thereby fostering a novel mode of interaction that transcends temporal and spatial boundaries while integrating the digital and the real^[4]. Building on this, it can construct tangible digital scenes, transforming the grand narrative of the Chinese national community into a perceptive process characterized by multi-modal experiences and strong engagement. This model not only vastly expands the spatiotemporal boundaries and audience reach of dissemination but also significantly enhances its emotional depth and cognitive efficacy through situational immersion and real-time interaction. Intelligent systems can further provide personalized content recommendations centered on themes like “ethnic unity”, fostering emotional connections and value consensus during interactions, thereby effectively strengthening the adhesion and resilience of identity.

The widespread application of new media creates structural opportunities for fostering a strong sense of community for the Chinese nation: it drives the transformation of publicity and education from one-way indoctrination towards participatory experience, enables high-quality, efficient, and targeted presentation, and vividly connects the historical trajectory of the Chinese nation to deepen the understanding of a shared sense of future, interests, honor, and responsibility. However, ideological contention within ethnic discourse in digital spaces has grown more complex. This reminds us that opportunities are accompanied by challenges. While actively embracing technological innovation, it is also necessary to prudently assess and address the new forms and issues of ideological engagement in the digital environment.

3. Multidimensional challenges in fostering a sense of community for the Chinese nation in the new media era

3.1. Cultural infiltration and identity challenges in the global arena

Amid the intertwined forces of globalization and digitization, new media have become a crucial arena for cultural dissemination and ideological contention. Leveraging their advantage in mediation, foreign cultures enter China’s information environment with unprecedented speed and breadth, continuously challenging the subjectivity and continuity of Chinese culture. This exerts sustained pressure that undermines the cohesion of the Chinese national community consciousness. While new media accelerates the cross-border flow of information and fosters cultural

exchange and mutual learning, it also intensifies conflicts and clashes of values. Certain groups, especially youth, immersed in diverse cultural information, may experience a gradual dilution of their identification with their own national culture. This potentially weakens the emotional foundation upon which community consciousness relies. Western developed countries, capitalizing on their first-mover technological advantages and platform dominance, conduct organized and systematic ideological output through new media. This often involves denigrating or even challenging China's mainstream values and ethnic policies in covert or distorted ways, thereby exacerbating risks and challenges within the ideological domain. The proliferation of new media has disrupted the relatively centralized discourse landscape of the traditional media era, leading to a redistribution of discursive power among diverse actors and increasingly complex communication ecosystems^[5]. In this process, negative information or one-sided views concerning ethnic factors are highly susceptible to amplification through new media's viral dissemination mechanisms. If manipulated and incited by those with ulterior motives, they could directly impact the stability of ethnic unity and social consensus.

3.2. Discursive fragmentation and consensus erosion in cyberspace

The virtual interaction space constructed by new media has profoundly reshaped the ways in which the public perceives communal consciousness and constructs identity. Due to the fragmented nature of content dissemination in media, the Chinese national community consciousness—which carries profound historical and value connotations—is prone to being fractured into isolated, superficial symbols or topics. This dilutes its significance as an authoritative public value and gradually disperses its inherent cohesive force in imperceptible ways^[6]. The digital media ecosystem has fostered numerous dissemination nodes, prompting extensive participation from diverse actors such as self-media creators, internet influencers, and ordinary users. On one hand, this has broken the traditional monopoly on discourse and unleashed the vitality of social expression; on the other hand, it has also sparked contention over the interpretive authority regarding ethnic narratives, potentially leading to new fissures within the Chinese national community amid its digital-intelligent transformation^[7]. In the discussions on ethnic issues on social media, some comments deliberately emphasize differences and ignore commonalities, cutting off the dialectical relationship between the diversity and unity of the Chinese nation. Extreme and labeled online debates continue to tear apart social consensus, putting greater pressure on official narratives to effectively guide public opinion, bridge differences, and rebuild consensus. The authority of professional media institutions has been diluted in the clamor, and the “sinking” of discourse power reflects democratization, but it is also accompanied by uneven discourse quality. The competition for traffic from multiple entities has squeezed the dissemination volume of mainstream media, and some one-sided, emotional, and even misleading information may distort the public's cognition, especially young netizens, and damage the overall image construction of Chinese culture. There is a tension between fragmented and emotional online expression and the systematic and rational interpretation required by mainstream ideology, making it difficult to aggregate the sense of community of the Chinese nation^[8].

3.3. Ecological and cognitive dilemmas under traffic dominance

Under the dominance of the platform economy, the logic of traffic profoundly governs content dissemination. Information concerning ethnic issues is prone to being caught in the race for traffic, becoming trivialized and sensationalized. Algorithms, prioritizing user engagement time, risk diminishing the depth and seriousness required for disseminating community consciousness. This subjects profound historical and cultural content to the danger of being reduced to easily consumable symbols, leading to constrained dissemination of high-quality

content and the hollowing out of cultural substance.

Personalized recommendation algorithms, based on user profiles, readily construct robust “information cocoons” and “echo chambers”^[9]. Users from different groups and regions become confined within highly homogenous information environments, systematically reducing their opportunities to encounter and understand the history, culture, realities, and developmental achievements of other ethnic groups. The richness and integrity of the Chinese nation’s “pluralistic unity” are filtered by algorithms into fragmented, even distorted, cognitive snippets, severely hindering deep understanding and emotional identification across groups. Should potential biases or blind spots in algorithm design combine with real-world structural disparities—such as differences in digital access capabilities and media literacy—the cultural expression and narrative discourse of frontier ethnic regions risk further marginalization within new media spaces. This makes it difficult for them to participate equally, fully, and deeply in the construction and shared meaning-making of the Chinese national community’s digital narrative.

The fusion of capital and technology, lacking effective value guidance and ethical regulation, can easily steer the dissemination of ethnic issues towards pure commercial logic and traffic competition. This trend not only creates and reinforces cognitive divides between groups but may also deconstruct, at a deeper level, the common foundation of cultural identity and erode the value bedrock of social solidarity.

4. Constructing integrated pathways to foster a strong sense of community for the Chinese nation

4.1. Strengthening top-level design and innovating cultural communication mechanisms

The General Secretary emphasized, “In the new era and new journey, the important position and role of the cyberspace industry are increasingly prominent”^[10]. New media have become a critical arena for international soft power competition. To foster a strong sense of community for the Chinese nation, it is essential to proactively grasp media trends, effectively guard against the impact of radical liberalism and harmful foreign cultures, and address disorders in digital communication. The General Secretary pointed out that people should use the power of the system to cope with the impact of risks and challenges^[11]. Efforts should be accelerated to improve the digital governance legal framework, integrating cultural security into the national strategic outlook with clear objectives and implementation rules. A comprehensive content security barrier must be constructed, with strengthened law enforcement and supervision to curb the spread of infringing and non-compliant information. A systematic approach is required to advance the digital transformation of traditional media from top-level planning to ground-level execution. This involves integrating media resources to build a new communication system with clear direction and extensive coverage, thereby expanding the reach for guiding mainstream values.

Driven by technology, the nation needs to enhance its capability and innovation in utilizing new media platforms, leveraging big data and artificial intelligence to revolutionize communication formats. Through deepening cultural system reform, it is essential to support and nurture influential cultural brands and enterprises. This will boost the efficacy and appeal of disseminating Chinese culture, consolidate the dominant position of mainstream ideology, guide the healthy development of digital interactions, delve into the profound connotations of various ethnic cultures, and foster their deep integration and symbiosis.

4.2. Integrating the communication ecosystem and reinvigorating cultural subjectivity

To cope with the dispersion of discourse power and fragmentation of content caused by algorithms, people

should promote the platform algorithm logic to shift from “traffic led” to “value led”, embed the core elements of community consciousness into the algorithm model, such as setting cultural content weight coefficients and establishing a social value evaluation mechanism for communication effects, to achieve a balance between commercial and social benefits. “Culture is the key to national identity”^[12]. Promoting the digital dissemination of culture can activate the national narrative and historical memory in culture, and help build a digital community for the Chinese nation.

To address the cognitive gap between digital natives and traditional mainstream discourse, “metaverse” technology can be employed to construct an immersive ethnic cultural experience space, thereby bridging the generational divide in cultural perception^[13]. By digitally reproducing historical scenes such as the Tea Horse Ancient Road and Princess Wencheng’s visit to Tibet, users can deepen their understanding of national history and ethnic integration through interactive experiences, making the digital space a new frontier that strengthens community consciousness. In a highly mediated society, it is necessary to construct a media ethics system that is in line with the core socialist values. Some platforms sacrifice their cultural mission in pursuit of traffic, promoting the dissemination of provocative content and eroding the foundation of social identity. Therefore, it is necessary to enhance the public’s ability to identify and criticize information, cultivate their sensitivity to information value, enhance their ability to resist cognitive risks, and eliminate the distortion of ideas caused by false narratives. By improving the ethical framework of algorithms, awakening users’ subjective consciousness, integrating fragmented cognition into systematic identification, and making the digital space truly a platform for consolidating social consensus.

To bridge the experiential gap between mainstream discourse and digital natives, new media forms such as the Metaverse can be leveraged to create immersive spaces for national cultural dissemination. By digitally recreating historical scenes—such as the Ancient Tea Horse Road or Princess Wencheng’s journey to Tibet—users can deepen their understanding of national history and ethnic integration through interactive experiences, transforming digital spaces into new frontiers for strengthening community consciousness. In a highly mediated society, it is imperative to establish a media ethics framework aligned with the core socialist values. Certain platforms, in pursuit of traffic, compromise their cultural mission, fueling the spread of inflammatory content and eroding the foundations of social cohesion. Therefore, it is essential to enhance the public’s ability to discern and critique information related to ethnic issues, cultivate sensitivity to information values, and bolster resilience against cognitive risks, thereby counteracting the distortions caused by false narratives. By refining the ethical framework for algorithms and fostering user agency, fragmented perceptions can be integrated into systematic identification, enabling digital spaces to genuinely serve as platforms for forging social consensus.

4.3. Regulating technology ethics and guiding algorithms for social good

Within the intelligent communication ecosystem, interest-driven recommendation mechanisms can easily derail the dissemination of ethnic issues from a rational track. They tend to reinforce biases and stereotypes, squeeze out space for reasoned dialogue, and imperceptibly construct digital barriers that hinder ethnic interaction. Furthermore, the fusion of capital and technology, if lacking ethical constraints, risks diluting the seriousness and depth required for fostering community consciousness, potentially rendering the guiding function of mainstream values ineffective.

Standardizing the operation order of digital platforms is an important guarantee for leveraging their educational empowerment role. On the supply side, people should encourage the development of cultural products

that comply with online ethics, integrate the concept of national rejuvenation into corporate culture, embed community consciousness indicators into the underlying architecture of recommendation systems, fully tap into and utilize Chinese cultural resources, and continuously optimize the online ecosystem. Platforms must improve their content review mechanisms, strengthen self-regulation, and enhance media discipline^[14]. It is essential to translate the core socialist values into actionable technological governance plans, genuinely implement the principle of “algorithm for social good”, and demonstrate the pace-setting role of official mainstream media in fostering a strong sense of community for the Chinese nation, thereby solidifying the defense line for national cultural security^[15].

The rise of new media has placed the construction of a strong sense of community for the Chinese nation within a more complex digital environment. This paper argues that the essence of this process is not merely technological application, but a profound inter-construction of media, culture, and identity. While new media reshape the pathways through which community consciousness is generated, they also introduce new challenges. Consequently, the core task lies in harnessing technology to systematically strengthen social bonds and cultural commonality within virtual spaces. Cyberspace has thus evolved into a critical strategic arena concerning cultural transmission, identity formation, and ideological security. Looking forward, dynamic governance wisdom is required to continuously adapt to technological and behavioral changes, ensuring that new media genuinely serve the fundamental goal of building consensus and solidifying the spiritual foundation of the community.

Disclosure statement

The authors declare no conflict of interest.

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Synthetic Biology Empowers Cosmetics to Enter a New Era of Biomanufacturing

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Abstract: With the rapid development of synthetic biology technology, the cosmetics industry has entered an unprecedented technological revolution. Against this background, this paper conducts research from two aspects: on the one hand, by analyzing the popular application of synthetic biology technologies such as gene editing, microbial fermentation, and enzyme engineering, the paper summarizes the breakthrough progress of the cosmetics industry in recombinant humanized collagen, natural plant functional ingredients, and new emulsification and stabilization systems; on the other hand, by elaborating on the advantages of synthetic biology in safety, efficacy, and sustainability in cosmetic production and manufacturing, the paper further looks forward to the future mature application and multi-disciplinary integrated development path. The aim is to promote the cosmetics industry to accelerate towards personalization, precision, and sustainable development, and truly usher in a new era of biomanufacturing.

Keywords: Synthetic biology; Biomanufacturing; Cosmetic raw materials; Recombinant collagen; Cell factory; Green manufacturing

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1. Introduction

With the development of the times and the continuous improvement of people's living standards, cosmetics have become one of the common consumer goods in human daily life. Their production and manufacturing have undergone an evolutionary path from extraction from natural animals and plants to chemical synthesis, and now to biomanufacturing, forming a complete and standardized production and manufacturing process. Traditional cosmetic raw material production methods have drawbacks such as strong resource dependence, high safety risks, and serious environmental pollution. Synthetic biology technology provides a solution: by designing and modifying biological systems and creating cell factories, it realizes efficient and green manufacturing of target products, providing unprecedented technical support for the transformation and upgrading of the cosmetics industry.

2. Analysis of new cosmetic functional ingredients in the field of synthetic biology

2.1. Recombinant humanized collagen: from structural bionics to functional transcendence

Collagen is one of the important components of the extracellular matrix of human skin cells, so it has long been a core functional ingredient of concern in the cosmetics field. Traditional collagen production methods from animal sources face risks such as viral contamination, functional limitations, and immunogenicity. Through genetic recombination and microbial fermentation technology, synthetic biology has achieved the safe and large-scale production of recombinant humanized collagen, fundamentally solving the production and application dilemmas of collagen ^[1].

In terms of technological development, the biosynthetic process of collagen is continuously upgrading. For example, Jinbo Biology has innovatively developed WeaveCOL collagen based on synthetic biology technology. It adopts a precise conformation of a 164.88° triple helix structure, thus achieving a high degree of consistency with human collagen, improving the repair effect of collagen's "structure repairing structure", and greatly enhancing its biological activity and compatibility, showing more prominent application effects in the cosmetics field ^[2].

In terms of industrial construction, recombinant collagen has achieved a leap from laboratory to large-scale production, and clarified the five-link production process of "gene design and optimization, gene synthesis and vector construction, protein expression, protein purification, and functional verification and quality control" ^[3]. It not only completely avoids potential risks from animal sources but also meets the manufacturing standards of environmental protection, controllability, and precision.

2.2. Natural herbal plant ingredients: From resource dependence to sustainable manufacturing

Traditional herbal plant resources have always had important advantages in the field of cosmetic manufacturing. However, plant extraction methods not only affect the ecological environment but are also affected by factors such as resource limitations, unstable ingredients, and low extraction efficiency. Synthetic biology has realized the biosynthesis of various rare active plant ingredients by constructing microbial cell factories, thus achieving an upgrade from resource dependence to sustainable manufacturing.

For example, natural plant-derived cosmetic ingredients such as terpenoid fragrances, ergothioneine, royal jelly acid, and *Lamiophlomis rotata* extracts traditionally need to be extracted from natural resources such as plants, fungi, and royal jelly ^[4]. Under the biosynthetic pathway, they can be continuously obtained through yeast cell factories, *Escherichia coli*/yeast engineering bacteria, genetically engineered bacteria, and plant cell culture. Taking terpenoid fragrances as an example, yeast cell factories can now achieve precise manufacturing of various terpenoid fragrances ^[5]. Such ingredients not only provide a good sensory experience but also have multiple physiological functions. For instance, β -caryophyllene can produce a woody spicy fragrance, has antibacterial and anti-inflammatory effects, and can be more efficiently absorbed by the skin ^[6].

2.3. Emulsification and stabilization systems: From chemical stabilization to biocompatibility

In cosmetic manufacturing, in addition to key ingredients that produce core skincare effects, ingredients such as emulsifiers, stabilizers, surfactants, and preservatives are also needed to ensure that cosmetics remain stable during storage and use, and achieve the effects and purposes of ease of use and rapid absorption. Therefore, emulsification and stabilization systems have become important factors affecting the stability and user experience of cosmetics. Most chemical emulsifiers used in traditional cosmetic production cause certain irritation, and their production

processes also increase environmental burden. Synthetic biology technology provides a green and safe alternative.

In terms of the research and development of stabilization system technology, the team of Jiang Lingxiang from South China University of Technology synthesized a new type of block polymer that can universally stabilize various “condensed phase-water phase” interfaces. Such molecules can protect and maintain the “condensed phase-water phase” interface by spontaneously forming a film layer, thereby improving the stability and tolerance of droplets ^[7]. This technology will play a significant role in the field of cosmetic manufacturing.

In terms of the research and development of emulsification system technology, a team from a Republic of Korean university used ultrasound to break microalgae and used their cell debris as emulsifiers, which showed excellent emulsifying and thickening properties in oil-in-water emulsions. At the same time, by regulating ultrasonic energy, more surface-active proteins can be better released from microalgae cells, thereby establishing a “cellulose-protein composite network”, which can reduce droplet size and increase viscosity, providing a new idea for the development of “green” emulsions without synthetic surfactants ^[8].

3. Advantages of synthetic biology in modern cosmetic production and manufacturing

3.1. Realizing green and sustainable manufacturing

Synthetic biology technology has essentially changed the traditional production and manufacturing processes of cosmetic raw materials, and gradually separated from the dependence on fossil resources and extraction from animals and plants, moving towards a green and sustainable manufacturing industry. In terms of resource utilization, glucose, corn, and other resources have become important raw materials for microbial fermentation processes, and reactions and synthesis are realized under normal temperature and pressure, with significant advantages of low energy consumption and low pollution. In terms of environmental impact, traditional cosmetic raw material production involves animal slaughter, plant collection, and consumes a large amount of water, chemicals, and chemical energy, resulting in significant environmental pollution and negative impacts. However, synthetic biology technology can effectively avoid most of these problems, reducing energy consumption by 15%–30%, carbon emissions by 20%–35%, and wastewater discharge by more than 50% ^[9]. In addition, synthetic biology can also provide a new approach for the protection and sustainable utilization of rare biological resources. For example, “giant salamander glycopeptides” can be isolated from the skin mucus of protected giant salamanders through bioenzymatic hydrolysis and refined extraction technology. This core active ingredient has important value in the field of cosmetic research and development ^[10]. At the same time, this production model can better promote animal protection and biodiversity development, achieving a win-win situation between ecological protection and industrial development.

3.2. Leapfrog improvement in product quality and safety

Synthetic biology has not only innovated the growth process of cosmetic raw materials but also fundamentally improved the quality and safety of cosmetics. First, through humanized ingredient design, it reduces rejection risks, improves the biocompatibility of cosmetic ingredients, and meets safety requirements at all levels, from raw material sources, structural characteristics, to functional realization. For example, in collagen production, the precise conformation of biosynthetic technology can not only solve the potential immunogenicity problems of traditional animal-derived collagen but also improve collagen activity and form an efficient communication mechanism with human cells, thereby achieving the effect of improving product repair functions ^[11]. Second, the

precise structure ensures the consistency and stability of efficacy. Cosmetic production under synthetic biology technology can accurately control the molecular structure of products, thus ensuring that products of different batches have the same quality level. Third, it realizes raw material purification and forms safety guarantees. Synthetic biology can rely on closed fermentation systems and other process methods to fundamentally cut off risk factors such as allergens and pathogens that may be carried by animal and plant raw materials.

3.3. Significant enhancement of production economy and flexibility

Synthetic biology technology can significantly improve the production efficiency of cosmetic raw materials and show higher flexibility, thereby achieving the purpose of improving economic benefits and market response capabilities. First, it has advantages in production efficiency and cost. With the support of metabolic pathways in microbial cell factories, synthetic biology technology can greatly increase the production speed of cosmetics, achieve magnitude breakthroughs in the output efficiency of some ingredients, and significantly reduce costs, which is conducive to the further popularization and promotion of original high-end cosmetic raw materials ^[12]. Second, production is more flexible and can meet customized needs. Synthetic biology platforms can quickly switch product production content to respond to market demands in a timely manner. For example, at this stage, the same strain of yeast can be promoted to synthesize multiple ingredients simultaneously through efficient metabolic transformation technology, achieving the effect of “one bacterium with multiple functions” ^[13]. Third, the innovation cycle is significantly shortened. Especially with the support of standardized biological parts and efficient gene editing tools, the speed of cosmetic research and development is rapidly increasing, and new products can be continuously launched.

4. Future outlook of synthetic biology empowering the development of the cosmetics industry

4.1. Technology innovation and industrial upgrading paths

The application and innovation of synthetic biology technology in the field of cosmetic production are on the ascendant, and it will continue to provide motivation in multiple dimensions to promote the upgrading of the cosmetics industry in the future. At the same time, with the continuous upgrading and popularization of gene editing technology, artificial intelligence, and high-throughput screening platforms, the biomanufacturing model of cosmetic raw materials will have a more precise and efficient development prospect.

From a technical perspective, multi-disciplinary cross-integration will become the core driving force for the further development and application of synthetic biology technology. From an industrial construction perspective, introducing relevant technologies from the laboratory to the factory is a key link that needs to be focused on to break through. The key to technology transformation lies in production costs, process feasibility, and market competitiveness. Therefore, the future technological innovation of synthetic biology in the cosmetics field will roughly develop in the following three aspects: first, the construction of high-efficiency chassis cells, aiming to develop universal chassis with strong adaptability and high yield ^[14]; second, the optimization and innovation of bioreactors, focusing on giving play to the advantages of digital technology; third, the innovation of downstream separation and purification technology, focusing on reducing purification costs and improving product recovery rate with the help of new separation materials and processes.

4.2. Industry ecology and value reconstruction

Synthetic biology technology provides a new cosmetic manufacturing model and reshapes the industrial chain, value chain, and development ecology of the cosmetics industry. Looking forward to the future, the application of synthetic biology in the cosmetics field will promote the transformation of the cosmetics industry from marketing-driven to technology-driven. It is necessary to highlight the value of technology and transform from “technology follower” to “standard setter” to demonstrate the core competitiveness of enterprises. From an individual perspective, synthetic biology will also help the cosmetics industry develop towards a new paradigm of personalized skincare. Especially with the support of cutting-edge sciences such as skin genomics and microbiomics, customized active ingredients and cosmetics can be provided according to the specific needs of different groups and individuals ^[15].

4.3. Global development and standard leadership

Synthetic biology technology also provides a shortcut for China’s cosmetic manufacturing enterprises to “overtake on curves.” On the one hand, synthetic biology technology has broken through the traditional routes and processes of cosmetic research and development, fundamentally bringing new opportunities for the global development of Chinese enterprises. Especially with the support of massive technological innovations, excellent Chinese cosmetic enterprises have gained unique competitiveness in the global market. On the other hand, with the in-depth application of synthetic biology in the cosmetics field, the construction of technical standard systems and regulatory frameworks has begun, which is not only a key route for the evolution of internal enterprise standards to industry standards but also an important channel to regulate market order and promote the healthy development of the industry.

5. Conclusion

In summary, synthetic biology is driving the cosmetics industry towards the era of biomanufacturing, and has reconstructed and improved it from the aspects of technology, industrial model, value concept, and industry structure. With the support of synthetic biology, modern cosmetic production models are safer, more efficient, and sustainable, and can effectively improve the economy and environmental friendliness of industrial production. It can even promote China’s cosmetics industry to move towards the world stage, gradually leaping from the “follower” stage to the “leader” stage, and realizing greater development aspirations.

Disclosure statement

The authors declare no conflict of interest.

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Work-Family Conflict and Career Success: Mediated by Work Engagement and Moderated by Work-Family Support

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Abstract: Against the backdrop of China's three-child policy, work-family conflict has become a prominent issue affecting employees' career development. This study explores the relationship between work-family conflict, work engagement, work-family support, and career success, using a sample of 533 employees from various enterprises across multiple regions in China. The results indicate that (1) work-family conflict has a significant negative impact on career success; (2) work engagement plays a partial mediating role in the relationship between work-family conflict and career success; (3) work-family support negatively moderates the relationship between work-family conflict and work engagement and weakens the mediating effect of work engagement. Practical implications for human resource managers are proposed to balance employees' work and family life and promote their career success.

Keywords: Work-family conflict; Work engagement; Career success; Work-family support

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1. Introduction

China's implementation of the three-child policy in May 2021 represents a pivotal demographic intervention amid accelerating population aging trends. Official statistics reveal that the national fertility rate plummeted to 1.3 in 2020, far below the replacement threshold of 2.1, while the proportion of citizens aged 65 and above is projected to exceed 20% by 2035. To counter this trajectory, the government has introduced complementary measures such as extended parental leave and childcare subsidies. However, these initiatives face systemic challenges in translating policy intent into tangible outcomes. The National Health Commission's 2022 National Fertility Intentions Survey uncovered a striking revelation: 68.3% of surveyed parents cited "work-family imbalance" as their primary barrier to additional childbirth, surpassing economic constraints and housing affordability. This paradox underscores a critical tension in contemporary China—while state policies aim to encourage population growth, workplace dynamics inadvertently perpetuate fertility hesitancy through rigid career expectations and

limited support systems.

The intensifying competition in China's labor market further exacerbates this dilemma. As urban professionals increasingly equate career advancement with social status and financial security, the psychological and temporal demands of professional success often collide with caregiving responsibilities. A 2023 study by the Chinese Academy of Social Sciences found that 76% of dual-earner households in tier-1 cities reported experiencing "chronic work-family spillover", where unpaid domestic labor disproportionately falls on women, even among managerial-level employees. This phenomenon aligns with global labor trends but carries unique cultural dimensions in China, where Confucian values emphasize filial piety, and filial obligations often intensify intergenerational caregiving burdens. The resulting strain on career trajectories poses a paradox: while career success remains a key motivator for workforce participation, its pursuit may inadvertently suppress fertility decisions through time deprivation and emotional exhaustion.

Existing scholarship on work-family conflict (WFC) has predominantly focused on its antecedents (e.g., job demands, spousal support) and outcomes (e.g., burnout, marital strain), with limited exploration of its nuanced relationship with career progression. This study proposes a moderated mediation model that integrates work engagement as a psychological mechanism and work-family support as a contextual buffer. The implications of this research extend beyond academic discourse. Human resources managers can adopt hybrid work models and mentorship programs to help employees navigate competing priorities. By elucidating the engagement-driven pathways through which WFC shapes career trajectories, this study bridges theoretical gaps in boundary theory and offers actionable strategies for managing demographic transitions in rapidly urbanizing economies.

2. Research hypotheses

2.1. Definition of core concepts

Work-Family Conflict: Adopting the definition by Greenhaus et al. (1985), it refers to the bidirectional interference between work and family roles due to incompatible time, behavior, or pressure, including two dimensions: work interfering with family and family interfering with work ^[1].

Career Success: Based on Eby et al. (2003), it includes career satisfaction (subjective dimension) and career competitiveness (objective dimension), reflecting employees' psychological sense of achievement and internal/external competitiveness in the workplace ^[2].

Work Engagement: Referring to Schaufeli et al. (2002), it is a positive work state consisting of three dimensions: vigor, dedication, and absorption, reflecting employees' emotional investment and behavioral participation in work ^[3].

Work-Family Support: According to Li Yongxin et al. (2009), it is a four-dimensional construct comprising organizational support, leadership support, emotional support, and instrumental support, encompassing various support resources from both work and family domains ^[4].

2.2. Research hypotheses

Work-Family Conflict and Career Success: From the perspective of role stress theory, work-family conflict is a typical form of inter-role conflict that generates continuous psychological stress for individuals. As a chronic stressor, it consumes employees' limited time, energy, and emotional resources, which are essential for maintaining high work efficiency and pursuing career development ^[5]. When employees are caught in the tug-of-war between work and family roles, they may have to sacrifice work tasks to cope with family affairs or neglect family

responsibilities to meet work demands, both of which can lead to declines in work performance and a sense of frustration in career development. In the long run, this will further reduce their career satisfaction and weaken their competitiveness in the job market, ultimately hindering their chances of achieving career success. Therefore, this study proposes:

H1: Work-family conflict has a significant negative impact on career success.

Mediating Role of Work Engagement: According to the conservation of resources theory, individuals strive to obtain and maintain valuable resources, and the loss of resources triggers negative psychological and behavioral responses. Work-family conflict essentially represents a loss of personal resources, which will trigger role pressure and emotional exhaustion, thereby weakening employees' work engagement^[6]. Work engagement, a positive, fulfilling work-related psychological state, comprises three core dimensions: vigor (high energy and resilience at work), dedication (strong involvement and a sense of significance at work), and absorption (full concentration and difficulty detaching from work)^[3]. High work engagement enables employees to actively invest in their work tasks, continuously improve work quality and efficiency, and thus gain more opportunities for promotion and development, which, in turn, promotes career success. It can be inferred that work-family conflict will reduce work engagement by consuming resources and, in turn, affect career success through work engagement. Based on this, this study proposes:

H2: Work engagement mediates the relationship between work-family conflict and career success.

Moderating Role of Work-Family Support: Social support theory holds that social support can act as a "buffer" to alleviate the negative impact of stressors on individuals by providing material or spiritual resources. Work-family support, as a specific form of social support in the work-family interface, includes multidimensional resources such as organizational support, leadership support, emotional support, and instrumental support^[4]. These support resources can help offset the resource loss caused by work-family conflict: for example, flexible working systems help employees balance work and family time; care and understanding from leaders reduce their psychological pressure; and organizational recognition of work-family balance enhances their sense of security. With sufficient work-family support, the negative impact of work-family conflict on work engagement will be weakened^[7]. Furthermore, since work engagement mediates the relationship between work-family conflict and career success, the moderating effect of work-family support on the conflict-engagement relationship will further influence the strength of the entire mediating path. Specifically, when the level of work-family support is high, the mediating effect of work engagement will be weaker; when the support level is low, the mediating effect will be stronger. Therefore, this study proposes:

H3: Work-family support negatively moderates the relationship between work-family conflict and work engagement.

H4: Work-family support moderates the mediating effect of work engagement between work-family conflict and career success, and the higher the level of work-family support, the weaker the mediating effect.

Based on the above hypotheses, this study constructs a moderated mediation model, with work-family conflict as the independent variable, career success as the dependent variable, work engagement as the mediating variable, work-family support as the moderating variable, and gender, age, and education level as control variables.

3. Research methods

3.1. Research sample

An electronic questionnaire survey was conducted among employees from various enterprises (state-owned,

foreign-funded, private, and public institutions) in Chongqing, Guangdong, Beijing, and other provinces or cities. A pre-survey with 55 questionnaires was conducted to optimize wording, and the formal survey was conducted from January to February 2024. A total of 556 questionnaires were collected, and 533 valid samples were obtained after excluding invalid ones, with an effective rate of 95.8%. Sample characteristics: 52.5% male, 47.5% female; 54.0% aged 21–30; 75.6% with a college or bachelor's degree.

3.2. Measurement

All scales adopted a 5-point Likert scale (1=strongly disagree, 5=strongly agree).

Work-Family Conflict: Greenhaus et al. (1985) scale, 10 items, Cronbach's $\alpha=0.91$.

Career Success: Eby et al. (2003) scale, 11 items, Cronbach's $\alpha=0.90$.

Work Engagement: Simplified UWES scale by Schaufeli et al. (2002), 9 items, Cronbach's $\alpha=0.88$.

Work-Family Support: Li et al. (2009) scale, 30 items, Cronbach's $\alpha=0.95$.

Control Variables: Gender (0=male, 1=female), age, education level (1=high school and below, 5=doctoral and above).

3.3. Data analysis methods

SPSS 24.0 and AMOS 23.0 were used for reliability and validity tests, correlation analysis, and regression analysis. The PROCESS plug-in (Model 4 and Model 7) tested mediating and moderated mediating effects using 5000 Bootstrap samples.

4. Research results

4.1. Reliability, validity, and correlation analysis

Cronbach's α coefficients of all variables exceeded 0.8, indicating good internal consistency. Confirmatory factor analysis showed the four-factor model had optimal fit indices ($\chi^2/df=1.15$, IFI=0.99, CFI=0.99, RMSEA=0.02), confirming convergent and discriminant validity. Work-family conflict was significantly negatively correlated with work engagement ($r=-0.43$, $P<0.001$) and career success ($r=-0.44$, $P<0.001$). Work engagement was significantly positively correlated with career success ($r=0.57$, $P<0.001$), providing preliminary support for hypotheses.

4.2. Hypothesis test

Main Effects: Work-family conflict negatively affected career success ($\beta = -0.43$, $P < 0.001$) and work engagement ($\beta = -0.42$, $P < 0.001$). Work engagement positively affected career success ($\beta = 0.56$, $P < 0.001$).

Mediating Effect: After adding work engagement, the effect of work-family conflict on career success decreased to $\beta = -0.24$ ($P < 0.001$). Bootstrap test confirmed a significant indirect effect (Effect = -0.19, 95% CI [-0.24, -0.15]), indicating partial mediation.

Moderating Effect: The interaction term of work-family conflict and work-family support positively affected work engagement ($\beta=0.25$, $P < 0.001$). The negative impact of conflict on engagement was weaker in the high-support group ($\beta = -0.15$) than in the low-support group ($\beta = -0.65$).

Moderated Mediating Effect: Bootstrap results showed mediating effects of -0.30 (low support), -0.18 (medium support), and -0.07 (high support), with a significant difference index (0.12, 95% CI [0.08, 0.15]).

5. Discussion and implications

Work-family conflict has a significant negative impact on career success, with bidirectional conflict reducing employees' career satisfaction and competitiveness. Work engagement partially mediates the relationship between conflict and career success, as conflict indirectly hinders career success by weakening work vigor, dedication, and concentration. Work-family support negatively moderates the conflict-engagement relationship and weakens the mediating effect of work engagement, with multi-dimensional support providing the strongest buffer.

Practically, this study suggests that human resources managers convey the value of balance through system publicity and case sharing, alleviating employees' psychological pressure; establish communication mechanisms to clarify supervisors' responsibilities for employees' family support and strengthen communication between enterprises and employees' families; enhance instrumental support to provide flexible leave for family emergencies and organize family-oriented team-building activities to balance work and family.

Limitations include convenience sampling, cross-sectional design, and self-reported data. Future research should expand sample coverage, adopt longitudinal tracking, and introduce additional variables (e.g., career resilience) to enrich the model.

Disclosure statement

The authors declare no conflict of interest.

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The Relationship Between Urban Resilience Construction and Economic Development from the Perspective of Environmental Geology — A Case Study of Shenzhen

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Abstract: Urban resilience is a key capability for contemporary cities to maintain core functions, recover quickly, and adapt to development when facing natural and social disturbances. From the fundamental perspective of environmental geology, this paper explores the intrinsic logical relationship between urban resilience construction and economic development in Shenzhen when addressing natural challenges such as geological hazards, coastal zone changes, and groundwater system fluctuations. The study argues that effective management of geological risks constitutes the physical foundation of urban economic resilience, while sustained economic development provides necessary material and technical support for enhancing geological safety resilience. The two form an interdependent and mutually promoting coupled system. Finally, the paper proposes an implementation path for constructing a “geological-economic” coordinated resilience system, aiming to provide theoretical reference and practical insights for Shenzhen and other similar coastal cities with high-intensity development.

Keywords: Urban resilience; Environmental geology; Economic development; Geological hazard prevention and control; Sustainable development; Shenzhen

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1. Introduction: The geological dimension in the era of resilient cities

Against the global backdrop of intensifying climate change impacts and frequent extreme weather events, “resilient cities” have become a core issue in modern urban development and governance ^[1-2]. Urban resilience emphasizes not only the ability to resist shocks but also the capacity to learn, adapt, and transform. For a megacity like Shenzhen, which is located along the coast, has complex landforms, and a highly concentrated economy,

a significant portion of the shocks and pressures it faces originates from the geological environment system on which it depends. Typhoons and heavy rains may trigger landslides, sea-level rise exacerbates coastal erosion, and engineering construction may disturb concealed karst — all these geological processes can pose severe challenges to the normal operation of the urban economy and society ^[3–5].

Therefore, examining urban resilience construction from the perspective of environmental geology essentially returns to the most fundamental level of cities as complex adaptive systems exchanging materials and energy with the natural environment. A resilient economic system can provide sustained investment and innovative momentum for the monitoring, assessment, governance, and adaptation of the geological environment. This paper aims to deeply analyze this often-overlooked geological dimension in Shenzhen's urban resilience construction and explain its inseparable symbiotic relationship with economic development.

2. Literature review

The theory of urban resilience provides a core framework for understanding cities' ability to maintain core functions amid disturbances, with its connotation evolving from engineering-oriented “recovery” to eco-social “adaptation and development” ^[6]. Within this framework, the geological environment, as the physical foundation of urban systems, its stability is a prerequisite for economic and social resilience. Studies have shown that the ability to resist geological hazards is directly related to urban lifeline safety and the continuity of economic operations, while geological processes such as coastal zone dynamics are key constraining factors for the sustainable development of the blue economy ^[7–8].

There is a profound interactive relationship between economic development and urban resilience. Strong economic strength provides necessary financial and technological support for resilience construction, enabling high-standard risk monitoring and infrastructure investment ^[9]; conversely, a safe and resilient environment can reduce operational risks, enhance investment confidence, and thereby feed back into long-term economic prosperity ^[10]. Domestic research has integrated resilience concepts into territorial spatial planning exploration, but case studies on Shenzhen mostly focus on climate risks, often treating geological issues as isolated technical challenges ^[11].

Thus, existing research has not fully revealed how Shenzhen's complex geological conditions systematically shape its economic resilience. This paper aims to fill this gap by placing environmental geology, urban resilience, and economic development within a unified framework, deeply analyzing their intrinsic logic, and providing a new perspective for Shenzhen's high-quality development.

3. Geological safety: The physical foundation of urban economic resilience

The resilience of an urban economic system is first reflected in the integrity and functionality of its physical infrastructure and production factors when facing disturbances. Environmental geological conditions are the core component of this physical foundation.

3.1. Infrastructure resilience and geological hazard prevention

Shenzhen's transportation networks, energy facilities, communication hubs, and high-density built-up areas are widely distributed across different geological risk zones. If a key expressway or subway line is interrupted due to slope failure, the direct economic losses and indirect impacts of industrial chain disruptions will be enormous.

Therefore, high-standard surveys, regular monitoring, and efficient governance of slope-related geological hazards are prerequisite conditions for ensuring the smooth flow of urban “blood vessels” and maintaining economic vitality. A city with high resilience to geological hazards will have significantly reduced vulnerability of its economic system to external shocks such as extreme weather^[12].

3.2. Spatial asset resilience and risks of karst and land subsidence

The risks of land subsidence and karst collapse faced by areas with soft soil and soluble rock directly threaten the safety of ground buildings and the long-term value of land assets. A sudden collapse incident not only causes direct property losses but also triggers regional credit impairment and undermines development confidence. Delimiting risk zones through high-precision geological surveys and conducting scientific planning and engineering avoidance based on this is the fundamental protection of social wealth and spatial assets. This proactive resilience construction is far more economically valuable than post-disaster reconstruction investment.

3.3. Water supply resilience and strategic groundwater reserves

Against the backdrop of Shenzhen relying mainly on the Dongjiang Water Diversion Project for its water supply, the economic role of groundwater resources has shifted from daily water supply to strategic emergency reserves. When surface water sources face supply crises due to sudden pollution or consecutive droughts, widely distributed and high-quality groundwater reservoirs can be quickly activated to provide guarantees for key industries and residents’ basic lives, avoiding economic and social shutdowns. Protecting groundwater from pollution and over-extraction, and maintaining its strategic reserve function, is a key link in building urban water supply resilience, whose value cannot be measured by short-term economic interests^[13].

4. Economic development: The core support for enhancing geological safety resilience

A city’s resilience to geological risks does not arise out of thin air; it highly depends on sustained economic investment, technological innovation, and institutional construction — all of which are backed by solid economic development^[14–15].

4.1. Financial support

The construction of advanced geological hazard monitoring networks, large-scale slope governance projects, coastal zone ecological restoration projects, groundwater resource surveys, and the delineation of protected areas all require substantial capital investment. Shenzhen’s strong public financial capacity and active social capital make it possible to carry out these tasks that enhance the city’s basic resilience.

4.2. Technological drive

Economic development promotes scientific and technological progress. Using InSAR satellite remote sensing technology for large-scale and high-precision surface deformation monitoring, adopting artificial intelligence algorithms to analyze massive geological data for collapse risk prediction, and developing new materials for ecological slope protection — these high-tech means have greatly enhanced cities’ ability to perceive, warn, and respond to geological risks, embodying “smart resilience.” Shenzhen’s industrial advantages in the information technology field can well empower the improvement of geological safety resilience.

4.3. Institutional guarantee

At a higher stage of economic development, society's demands for safety, environmental quality, and sustainable development become increasingly strong, thereby promoting the formation of stricter land use controls, building codes, and environmental regulations. For example, Shenzhen took the lead in the country in formulating systematic geological hazard prevention and control plans and detailed survey and zoning — this itself is a reflection of the upgrading of social demand for public goods such as safety after economic development reaches a certain stage, and the construction of institutional resilience.

5. Path suggestions for constructing a “geological-economic” coordinated resilience system

To deeply embed geological safety into the core of urban economic development and realize a paradigm shift from passive prevention to active adaptation, and from cost burden to value creation, Shenzhen needs to strive to build a forward-looking and systematic “geological-economic” coordinated resilience system. The construction of this system should follow the following four strategic paths.

5.1. Conceptual innovation path: Strategic upgrade from “disaster prevention and reduction” to “resilience value addition”

Establish a new development concept of “geological resilience as core competitiveness”: In urban top-level design, clearly regard geological safety resilience as a core urban competitiveness equal to the business environment and technological innovation. Advocate the concept that “investing in resilience is investing in future value increment”, guiding the whole society to recognize that excellent geological risk management capacity is itself a “distinctive urban asset” for attracting high-end talents and ensuring long-term capital safety.

Promote the “mainstreaming” and “front-loading” of resilience thinking: Shift geological resilience considerations from “engineering remedial measures” in the later stages of projects to the source stage of territorial spatial planning, industrial policy formulation, land transfer, and feasibility studies of major projects. Set up a special “urban resilience” chapter in urban development strategies and national economic and social development plans to ensure that geological safety and economic development goals are planned and deployed simultaneously.

Define and promote “resilience value”: Go beyond the traditional cost-benefit analysis framework and establish a “resilience value” evaluation system. This system should comprehensively consider the risk avoidance benefits, whole-life cycle cost savings, ecological system service value improvement brought by geological safety measures, as well as the resulting regional brand value increment and investment confidence enhancement, providing a more comprehensive demonstration of the economic rationality of resilience construction projects.

5.2. Institutional innovation path: Constructing a comprehensive and whole-chain resilience governance system

Establish an integrated “geological-planning-economic” decision-making platform: It is recommended to set up a high-level cross-domain “Urban Resilience Development Committee” at the municipal level, led by municipal leaders, to coordinate the powers and responsibilities of departments such as natural resources, development and reform, finance, housing and urban-rural development, water affairs, transportation, and emergency management. The committee is responsible for reviewing the city's overall resilience development strategy, coordinating the resolution of major contradictions involving geological safety and economic development, and ensuring policy

coordination.

Improve the “space-property-rights-finance” linked policy toolbox: Spatial control: On the basis of China’s territorial spatial planning boundaries “three zones and three lines”, further refine and issue the “Shenzhen Municipal Spatial Control Rules for Geological Hazard Prevention and Control and Geological Environment Protection”, clarifying prohibited, restricted, and guided development requirements for areas with different geological risk levels.

Property right incentives: Explore the establishment of a “transfer and transaction mechanism for geological safety development rights.” Allow land rights holders in high-geological-risk ecological sensitive areas to transfer their restricted development rights to concentrated construction areas with suitable geological conditions, realizing Pareto improvement in ecological protection and economic development.

Green finance: Cooperate with financial institutions to innovate and launch financial products such as “urban resilience bonds”, “special loans for geological hazard prevention and control”, and “resilient building insurance.” Provide policy incentives such as green credit interest subsidies and floor area ratio rewards for real estate development and infrastructure projects adopting high-standard resilience design and technologies, guiding market capital to actively flow into the field of resilience construction.

5.3. Technology empowerment path: Building an intelligent and precise resilience support system

Construct an “urban geological digital twin platform”: Integrate data from geological surveys, Internet of Things monitoring, InSAR remote sensing, BIM/CIM, etc., to build a comprehensive, full-element, and whole-process urban geological information model. This dynamically updated “digital foundation” can simulate and predict changes in the geological environment under different climate scenarios and engineering activities, providing “sand table deduction”-style decision support for urban planning, project site selection, and risk early warning.

Build an “intelligent risk perception and emergency dispatch” network: Based on the digital twin platform, establish an intelligent monitoring and early warning network covering key risk areas. Use artificial intelligence and big data models to achieve advanced prediction, precise judgment, and rapid early warning of risks such as geological hazards, land subsidence, and seawater intrusion. Once a danger occurs, the system can automatically match emergency resources, generate optimal disposal plans and evacuation routes, realizing a leap from “human prevention” to “intelligent prevention.”

5.4. Market and social participation path: creating a co-construction and sharing resilience ecosystem

Cultivate new formats of the “resilience industry”: Relying on Shenzhen’s advantages in information technology, high-end equipment, and environmental protection industries, encourage and support enterprises to develop technologies, equipment, and services related to geological surveys, monitoring and early warning, ecological restoration, and emergency rescue. Transform the process of addressing geological challenges into an opportunity to cultivate new economic growth points and build a “resilience technology” industrial cluster.

Construct a market-oriented mechanism of “risk sharing and benefit sharing”: Fully implement the PPP (Public-Private Partnership) model in the field of geological hazard prevention and control projects. Deepen the “geology-insurance” linkage, develop innovative products such as index insurance and catastrophe insurance, and use market-oriented means to smooth the fiscal impact caused by disasters, forming a positive economic cycle of

“disaster prevention and loss reduction — premium reduction.”

Improve the geological risk literacy of the whole society: Regularly release an easy-to-understand “Shenzhen Urban Geological Safety White Paper” and risk maps, and open geological parks and monitoring stations as popular science education bases. Through community publicity, school education, media communication, and other methods, improve the cognitive level and independent response capabilities of citizens, enterprises, and grass-roots staff to geological risks, and build a grass-roots defense line for urban resilience construction.

Through the coordinated advancement of the above four paths, Shenzhen will be able to construct a “geological-economic” coordinated resilience system guided by conceptual innovation, guaranteed by institutional innovation, supported by technology empowerment, and driven by market and social participation. This can not only effectively resolve the threat of geological risks to economic development but also transform the “constraints” of geological safety into a unique advantage driving the city towards a higher-quality and more sustainable future, providing a “Shenzhen solution” for the sustainable development of high-intensity development megacities worldwide.

6. Conclusion

From the perspective of environmental geology, Shenzhen’s urban resilience construction and economic development are not two parallel lines but an intertwined and mutually reinforcing spiral upward chain. Geological safety provides a stable spatial carrier and resource guarantee for economic activities, serving as the material prerequisite for economic resilience; while sustained and healthy economic development provides a steady stream of technical, financial, and institutional supply for understanding, managing, and adapting to geological environment risks, acting as the fundamental driving force for enhancing geological safety resilience. Facing the future, Shenzhen should more consciously identify and strengthen this coordinated relationship, deeply implant geological resilience thinking into the genes of urban development, thereby building a truly resilient global benchmark city that can calmly respond to natural disturbances and maintain economic innovation vitality in an uncertain world.

Disclosure statement

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Research on the Connotation Interpretation, Realistic Dilemma, and Mechanism Construction of Educator Spirit in the New Era

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Abstract: The state attaches great importance to the construction of the teachers' team, from "four have" good teachers to "great teachers", and then to the evolution of the concept of "educator teacher", and finally condensed into the spirit of educators with Chinese characteristics. This spiritual system takes six dimensions as the core, such as "the ideal and belief of serving the country with sincerity", which is the inheritance of the Chinese excellent educational tradition and the major innovation of the sinicization of Marxist educational theory. In the critical period of building a strong education country, it is of great theoretical significance and practical value to deeply explain the theoretical origin and the value of the times of the educator's spirit, to solve its practical dilemma in carrying forward and implementing, and to construct a scientific and efficient practical mechanism. This paper systematically combs the connotation and generation logic of educator spirit, analyzes the existing problems in connotation interpretation, transformation path, and guarantee system, and puts forward the three-dimensional implementation mechanism of "cultural guidance-practical empowerment-institutional guarantee", which provides theoretical support and practical path for the construction of teachers' team and the high-quality development of education in the new era.

Keywords: Educator spirit; Education power; Vocational education; Ideological and political education

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1. Introduction

A strong country must first strengthen education, and a strong education must first strengthen teachers. Teachers are the foundation of education and the source of education. The proposal of the spirit of an educator is the inheritance and innovation of the thousands of years of educational civilization of the Chinese nation. It is the theoretical sublimation of the practical experience of education since the founding of the People's Republic of China. It is also the inevitable requirement to cope with the educational reform in the new era and meet the people's demand for high-quality education. At present, China's education is in a critical period of transformation

from scale expansion to quality improvement, facing multiple challenges such as digital transformation, education model reform, intensified international competition, and the development of new quality productivity. In this context, carrying forward and implementing the spirit of educators is not only the internal need to improve teachers' professional quality and moral sentiment, but also the core driving force to solve the problems of education development and promote the high-quality development of education.

2. Connotation interpretation and generation logic of the educator spirit in the new era

The educator spirit is a spiritual system rooted in the profound historical and cultural soil, relying on scientific theoretical guidance and conforming to the development needs of the times. Accurately grasping its core connotation and clarifying its core connotation and generation logic are the premises of deeply understanding the spiritual essence of educators and promoting their effective practice.

2.1. The core connotation of the educator spirit

The educator's spirit covers the following six dimensions: the ideal and belief of "having a big heart and serving the country sincerely", the moral sentiment of "being a scholar and acting as a model", the educational wisdom of enlightening wisdom and moistening the heart and teaching students in accordance with their aptitude, the attitude of diligence and innovation, the heart of benevolence of loving students and being willing to devote, and the pursuit of promoting the world with the mind and educating people ^[1]. It constitutes a spiritual system with strict logic and rich connotation.

The ideal and belief is the soul of the educator's spirit. It emphasizes that teachers should integrate personal ideals into the great cause of national development and national rejuvenation, which reflects the family and country feelings and mission of education. Yan Yangchu's participation in the civilian education movement and Zhang Boling's "three questions of patriotism" are vivid portrayals of ideals and beliefs.

Moral sentiment is the foundation of the body, requiring teachers to lead by example, be a model for others, and become a model for students' moral cultivation. Ideological and political teachers should adhere to the principle of "strong politics, deep feelings, new thinking, wide vision, strict self-discipline, and correct personality" ^[2].

Educational wisdom is the core competence, which highlights the professionalism and scientificity of education and requires teachers to follow the law of education and the law of students' growth. Vocational education teachers need to balance skill teaching and value guidance in the integration of production and education. Basic education teachers should teach students in accordance with their aptitude under the pressure of further education. College teachers should solve the problem of "emphasizing research and neglecting teaching" and realize the equal emphasis on teaching and research.

The attitude of farming reflects the teacher's academic spirit and enterprising consciousness, emphasizing lifelong learning and innovative practice. Vocational education teachers need to conform to the development trend of new productivity, go deep into the practice of enterprises to master new technologies and new skills, and college teachers should continue to improve in academic research and teaching reform.

The heart of benevolence is the emotional basis of education, highlighting the student-centered concept of education. "Holding a heart without half a grass" is the ideal interpretation of the spirit of teacher love.

The pursuit of Hongdao shows the cultural mission and international vision of education. It requires teachers to inherit Chinese excellent culture and promote the exchange and mutual learning of civilizations. It is the concrete embodiment of Hongdao's pursuit that vocational education teachers' overseas teaching serves international production capacity cooperation.

2.2. The generative logic of the educator's spirit

2.2.1. Historical origin: Inheritance and innovation of the Chinese excellent education tradition

The spirit of Chinese traditional educators is deeply rooted in the soil of Chinese excellent traditional culture. It takes "self-cultivation" as the core and emphasizes the heart of "sincerity" and the feelings of home and country. From Confucius "educational proposition of "education without discrimination", Zhang Zai's mission of "building the heart for the heaven and the earth, and building the life for the people", to Zhu Xi's academic attitude of "studying things to acquire knowledge", the elements of benevolence, integrity, practice and responsibility in the traditional educational spirit provide profound cultural nourishment for the spirit of educators in the new era. Since modern times, Cai Yuanpei's school-running concept of "ideological freedom and inclusiveness", Tao Xingzhi's practical proposition of "life is education", Meng Xiancheng's exploration of the integration of Chinese and Western educational thoughts, the formation of patriotic dedication, the pursuit of truth, and the unity of knowledge and practice have further enriched the connotation of the spirit of Chinese educators and laid a historical foundation for its formation in the new era.

2.2.2. Theoretical guidance: The sinicization and modernization of Marxist educational theory

Marxist educational theory emphasizes the class nature, people's nature, and practicality of education, and advocates that education serves the cause of the proletariat and promotes the all-round development of people. In contemporary China, this theory is combined with Chinese educational practice, forming the fundamental task of "building morality and cultivating people" and the educational policy of "five educations simultaneously." The spirit of educators is the spiritual condensation of these theoretical achievements, which embodies the innovative development of Marxist educational theory in the new era. Especially in the field of ideological and political education, Marxist theory provides a solid theoretical support for the spirit of educators.

2.2.3. The needs of the times: The practical call for the construction of a strong education country

As China enters the stage of high-quality development, education undertakes the important mission of cultivating socialist builders and successors with all-round development of morality, intelligence, physique, beauty, and labor^[3]. In the face of the new requirements of digital transformation, industrial upgrading, and new productivity development for talent training, and the urgent needs of the people for high-quality and balanced education, education reform and development need strong spiritual guidance. As the main position of cultivating technical and skilled talents, vocational education urgently needs to lead the construction of "double-qualified" teachers with the spirit of educators. Higher education is facing the dual tasks of "double first-class" construction and independent training of talents, which requires the spirit of educators to stimulate teachers' enthusiasm for educating people; basic education needs to improve the quality of education with the spirit of educators under the background of the "double reduction" policy. The proposal of educator spirit is the inevitable result of responding to the demands of the times, which provides spiritual impetus for solving the problems of education development and improving the quality of education.

3. The realistic dilemma of carrying forward and implementing the educator's spirit

In the current process of carrying forward and implementing the educator spirit, it still faces a series of practical difficulties. These difficulties not only restrict the effective dissemination and deep recognition of the educator's spirit, but also hinder its transformation from spiritual concept to teaching practice, affecting the effectiveness of teacher team construction and education quality improvement.

3.1. Cognitive level: The fragmentation of connotation interpretation

At present, there is a problem of fragmentation in the interpretation of the connotation of the spirit of educators. Some educators only pay attention to the understanding of a single dimension and lack the overall grasp of the spiritual system, resulting in one-sided cognition. For example, some vocational education teachers simply equate the spirit of educators with the spirit of craftsmen, ignoring the core dimensions of ideals, beliefs, and pursuits; college teachers may focus on scientific research and innovation in the attitude of self-cultivation, weakening the cultivation of educational wisdom and benevolence.

3.2. Practical level: fuzzy transformation path

In the process of practice transformation, some schools and teachers have the phenomenon of “emphasizing form and neglecting effectiveness.” Carrying forward the spirit of educators is simply equivalent to carrying out thematic activities and posting propaganda slogans, lacking the specific path of transforming spiritual connotation into teaching behavior. There is an imbalance between supply and demand in the practice transformation in different education fields: college teachers are faced with the guiding influence of “emphasizing research and neglecting teaching”, the weight of scientific research evaluation is too high, and it is difficult to fully integrate the wisdom of educating people and the attitude of hard work into teaching practice. Some teachers even regard teaching as a “sideline” and ignore the fundamental task of moral education.

3.3. Institutional level: The security system is not perfect

In terms of the guarantee system, the teacher training system lacks pertinence. The existing training is mostly general content, and it fails to design personalized training programs based on the characteristics of teachers in different periods, different disciplines, and different fields. The training of vocational education teachers focuses more on theoretical knowledge and lacks practical skills training in enterprises. The training of ideological and political teachers lacks the deep integration of value guidance and teaching methods; the lack of training resources for teachers in rural areas makes it difficult to obtain high-quality learning opportunities. The protection mechanism of teachers' rights and interests is not perfect. Some teachers are facing problems such as high work pressure, limited space for career development, and low salary. In particular, the social status and economic treatment of vocational education teachers need to be improved, which affects the enthusiasm of practicing the spirit of educators.

4. Construction of the mechanism for carrying forward and implementing the spirit of educators

To solve the practical dilemma in the promotion and implementation of the educator's spirit, it is necessary to build a scientific system and a practical mechanism. Based on the previous analysis of the connotation and dilemma, a three-dimensional implementation mechanism of “cultural guidance-practical empowerment-

institutional guarantee” is proposed.

4.1. Cultural leading mechanism: Strengthen cognitive identity and atmosphere construction

Innovate diversified communication paths: integrate traditional media and new media resources, and build a communication system of “policy interpretation + case sharing + interactive communication.” Use new media carriers such as short video platforms and educational apps to produce vivid and engaging communication content, such as vocational education teachers’ enterprise practice records, ideological and political teaching innovation cases, and excellent teachers’ education stories. Carry out offline activities such as “educator spirit into campus”, “famous teacher lecture hall” and “craftsman master into campus”, and invite excellent teachers, industry experts and craftsman masters to share practical experience; establish a cross-regional and cross-domain learning and communication platform, and narrow the cognitive gap between regions and fields through online live broadcast, offline mutual visits, and teacher studio pairing. Pay special attention to the coverage of teachers in rural areas and remote areas, and ensure the accessibility of learning resources by sending teachers to the countryside and providing online training.

Strengthen the culture of respecting teachers and valuing education: increase the recognition of teachers’ honors, improve the three-level recognition system at the national, provincial, and school levels, and focus on recognizing teachers who have achieved remarkable results in practicing the spirit of educators. In the field of vocational education, the establishment of the “double-qualified” teacher model, vocational education teacher and other honorary titles; in the field of ideological and political education, select famous teachers of ideological and political courses and excellent ideological and political workers; in colleges and universities, promote the “double name plan” and cultivate educator-type famous teachers and principals. Tell the story of Chinese educators well, excavate the typical cases of excellent teachers in different fields, such as Zhang Guimei, Yu Yi, etc., widely publicize through various channels, and create a social fashion that advocates the spirit of educators. To integrate the spirit of educators into the construction of campus culture, vocational colleges can set up industry models and craftsmen master sculptures, colleges and universities can build educators memorial halls and school history halls, basic education schools can arrange typical portraits of sages and people’s educators, forming a campus atmosphere of “everyone practicing the spirit of educators.”

4.2. Practice empowerment mechanism: Build a transformation platform and enhance the ability

Build a practice transformation carrier: establish an “educator’s spiritual practice base”, select different types of schools to carry out pilot projects, such as the “craftsman cultivation” base of vocational undergraduate colleges, the “double name plan” practice base of colleges and universities, and the famous teacher studio of basic education, and explore a replicable and replicable practice model. Carry out the theme practice activities of “practicing the spirit of educators”, and vocational education can organize teachers’ enterprise practice results display and skill teaching innovation competition; colleges and universities can hold teaching innovation forums and educational achievements exchange meetings; basic education can carry out teaching design competitions and share educational stories; teachers of ideological and political courses can organize red education practice, social hot spot discussion, etc., and promote teachers to transform spiritual connotation into specific teaching behavior. Build a teacher practice community, encourage interdisciplinary, cross-school, cross-field teacher exchanges and

cooperation, and use project research, project cooperation, and famous teacher studios as carriers to share practical experience and jointly solve practical problems. For example, vocational education teachers and enterprise technical experts form a community to jointly develop curriculum resources; teachers of ideological and political courses cooperate with teachers of professional courses to promote the construction of ideological and political courses.

Strengthen digital literacy and technology application ability: incorporate digital literacy into the core content of teacher training, and carry out special training such as intelligent teaching tool application, online teaching method, and big data analysis according to the needs of teachers in different fields. Vocational education teachers focus on learning virtual simulation teaching technology and digital training platform operation; college teachers focus on the digital retrieval of academic resources and the application of online teaching platform; basic education teachers strengthen the production of multimedia teaching resources and students' ability to learn data analysis; teachers of ideological and political courses need to master new media communication technology and online value guidance methods. Build a digital teaching resource library, integrate high-quality teaching cases, teaching design, virtual simulation resources, etc., cooperate with the national smart education platform, and provide technical support for teachers to practice the spirit of educators. Guide teachers to correctly handle the relationship between technology and education, adhere to the original intention of educating people in intelligent teaching, avoid technological alienation, teach students in accordance with their aptitude through technological empowerment, and enhance teacher-student interaction and emotional communication.

4.3. Institutional guarantee mechanism: Improve the evaluation incentive and support system

Reform the education evaluation mechanism: establish a three-dimensional evaluation system of “teacher ethics + education effectiveness + professional development”, and take the practice of educator spirit as the core index of teacher evaluation. Colleges and universities should adjust the weight of evaluation, improve the proportion of teaching performance, education effect and curriculum ideological and political construction effect in title evaluation and performance evaluation, and reduce the excessive weight of scientific research results; the basic education reforms the way of student evaluation, pays attention to the overall development of students and the improvement of comprehensive quality, integrates the cultivation of students' moral character and the development of ability into the evaluation system, and creates a relaxed environment for teachers to practice the spirit of educators; vocational education establishes a school-enterprise collaborative evaluation mechanism, incorporates enterprise practice results, education results, and technical service capabilities into the teacher evaluation system, and improves the evaluation weight of skill teaching and integration of production and education. The evaluation of ideological and political teachers focuses on indicators such as political literacy, value-leading effectiveness, and students' ideological transformation, and adopts a combination of student evaluation, peer evaluation, and expert evaluation. Use big data, artificial intelligence, and other technologies to improve diversified generative evaluation, give full play to the evaluation role of industry enterprises, parents, and students, and reverse the utilitarian tendency of teachers.

Improve the teacher security system: improve the teacher salary guarantee mechanism, improve the income level of teachers, narrow the gap between urban and rural areas, regions, inter-schools, and teachers in different education fields, especially improve the salary and social status of teachers in vocational education and rural areas. Establish a teacher career development channel to provide clear promotion paths for teachers at different

levels, such as the “double-qualified” title promotion channel for vocational education teachers, the teaching-type and research-type parallel promotion path for college teachers, and the special promotion channel for ideological and political teachers to stimulate career development. Strengthen teachers’ mental health services, establish psychological counseling and stress counseling mechanisms, and relieve teachers’ work pressure, especially pay attention to the pressure of basic education teachers, the pressure of scientific research of college teachers, and the multi-task pressure of vocational education teachers. Educators will implement the teacher’s “burden reduction” mechanism, reasonably arrange the workload of teachers, reduce unnecessary administrative affairs, meetings, supervision, and inspection, and give teachers more time and energy to carry out teaching, scientific research, and education ^[4].

5. Conclusion

With the continuous deepening of education reform and the sustainable development of the era of digital intelligence, the connotation of the spirit of educators will continue to be enriched, and the implementation mechanism also needs continuous innovation. The promotion and implementation of the educator’s spirit is a long-term and arduous task, which requires the unremitting pursuit and practice of generations of educators. It is believed that under the joint efforts of the administrative departments of education, schools, society, families and other subjects, through the guarantee of a sound implementation mechanism, the spirit of educators will be deeply integrated into the whole process of education and teaching, and transformed into the professional beliefs and action consciousness of the majority of teachers, so as to inject inexhaustible impetus into the construction of a strong country in education and cultivate more socialist builders and successors with all-round development of morality, intelligence, physique, art and labor for the great rejuvenation of the Chinese nation.

Disclosure statement

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Should Ecocide Be Criminalized in the European Union? — A Normative Legal Analysis from an EU Environmental Criminal Law Perspective

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Abstract: The concept of ecocide has re-emerged in contemporary legal and policy discourse as a response to large-scale and irreversible environmental destruction. Within the European Union (EU), increasing concern over climate change, biodiversity loss, and corporate accountability has intensified debates on whether ecocide should be recognized as a criminal offence under EU law. This article examines the legal, philosophical, and normative justifications for the criminalization of ecocide in the EU. Through a doctrinal and normative legal analysis, the article evaluates the adequacy of existing EU environmental and criminal law frameworks, explores the relationship between environmental protection and human rights, and assesses alternative regulatory approaches. The article argues that current legal mechanisms remain fragmented and insufficient to address severe environmental harm and that the criminalization of ecocide would fulfil both preventive and expressive functions within EU law. The article concludes that the adoption of a harmonized and comprehensive definition of ecocide is a necessary step towards strengthening environmental protection and legal accountability in the European Union.

Keywords: Ecocide; European Union; Environmental crime; Criminal law; Human rights; Environmental protection

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1. Introduction

Environmental degradation has become one of the most pressing challenges of the twenty-first century. Climate change, biodiversity loss, pollution, and large-scale ecosystem destruction increasingly threaten not only ecological integrity but also human health, security, and socio-economic stability^[1]. In response to these challenges, the concept of ecocide has gained renewed attention in international and regional legal discourse^[2–3]. Broadly understood as the widespread or systematic destruction of the natural environment, ecocide has been proposed as a crime warranting the most serious legal condemnation^[4].

Within the European Union (EU), environmental protection has long been recognized as a core policy

objective. Nevertheless, despite an extensive body of environmental regulation, severe environmental harm continues to occur, often with limited accountability for those responsible^[5]. This has prompted renewed debate as to whether existing regulatory and administrative mechanisms are sufficient, or whether criminal law should play a more central role^[6].

This article examines whether and to what extent the criminalization of ecocide within the EU legal order can be justified. It addresses the following research question: Does the current EU legal framework adequately address large-scale environmental destruction, and would the criminalization of ecocide provide a more effective and coherent response? The article proceeds in six parts. Following this introduction, Section 2 examines the conceptual foundations and contested definitions of ecocide. Section 3 analyses the normative and philosophical rationales for criminalizing ecocide in the EU. Section 4 evaluates the adequacy of existing EU legal frameworks in addressing severe environmental harm. Section 5 considers alternative, non-criminal approaches to addressing ecocide and assesses their limitations. Section 6 concludes by outlining the implications of criminalizing ecocide for EU law and policy.

2. Conceptualizing ecocide

The term ecocide is derived from the prefix “eco-”, referring to the environment, and the suffix “-cide”, denoting killing or destruction. It is commonly understood as the extensive damage to, destruction of, or loss of ecosystems, whether caused deliberately or through reckless conduct^[3–4]. While the concept emerged prominently in the 1970s, particularly in response to the environmental devastation caused by the use of chemical agents during the Vietnam War, it has since evolved into a broader legal and normative category^[4].

Scholarly attempts to define ecocide have varied in scope and emphasis. Some definitions focus on intent and deliberate conduct, while others extend to reckless or negligent actions that result in severe and long-term environmental harm. The Independent Expert Panel for the Legal Definition of Ecocide, convened in 2021, proposed defining ecocide as unlawful or wanton acts committed with knowledge that there is a substantial likelihood of severe and either widespread or long-term damage to the environment. While this formulation represents a significant step towards legal clarity, it has also attracted criticism for its perceived restrictiveness.

The definitional debate is not merely semantic. In criminal law, clarity and precision are essential to ensure legality, foreseeability, and effective enforcement. An overly narrow definition risks excluding harmful conduct that ought to attract criminal liability, while an overly broad definition may undermine legal certainty. For the EU, which operates within a complex multi-level legal system, the challenge lies in developing a definition of ecocide that captures the gravity of environmental destruction while remaining compatible with fundamental principles of criminal law^[7–8].

3. Rationale for criminalizing ecocide in the European Union

3.1. Philosophical and normative foundations

Criminal law serves not only to punish wrongdoing but also to express societal condemnation of conduct deemed intolerable^[9–10]. In the context of environmental harm, regulatory approaches have traditionally prioritized mitigation and compliance rather than outright prohibition. However, where environmental destruction reaches a scale that threatens ecological security and human survival, regulatory measures may be insufficient^[11].

Advocates of criminalizing ecocide argue that total prohibition, rather than mere regulation, is necessary to

address such harm. As Higgins has argued, criminalization represents a “trim tab” capable of triggering broader systemic change by reshaping corporate and governmental behavior. From this perspective, ecocide constitutes a moral and legal wrong of such magnitude that it warrants the strongest form of legal censure ^[12].

3.2. Censure, deterrence, and the expressive function of criminal law

Theories of criminalization emphasize the role of criminal law in censuring conduct that causes unreasonable harm. According to Gardner and Feinberg, criminal sanctions serve not merely instrumental purposes but also communicate societal condemnation. Environmental destruction on a massive scale causes harm that is irreversible, transboundary, and intergenerational, thereby meeting the threshold of seriousness traditionally associated with criminal offences ^[6-8].

The criminalization of ecocide would also serve a deterrent function. While deterrence alone cannot justify criminalization, it remains relevant where environmental harm is often driven by economic incentives. The prospect of criminal liability, particularly for corporate executives and decision-makers, may encourage greater consideration of environmental risks and foster more responsible conduct.

3.3. Human rights and environmental protection

An increasing body of scholarship recognizes the intrinsic link between environmental protection and human rights. A safe, clean, healthy, and sustainable environment is now widely regarded as a prerequisite for the enjoyment of fundamental rights, including the rights to life, health, food, and water. This understanding has been reflected in the United Nations General Assembly’s recognition of the right to a healthy environment ^[13].

Within the EU context, environmental degradation has direct implications for human rights protection. Severe pollution, ecosystem collapse, and climate-related disasters disproportionately affect vulnerable communities and future generations. Criminalizing ecocide would therefore not only protect the environment as an autonomous interest but also reinforce the EU’s commitment to fundamental rights.

4. Adequacy of the existing EU legal framework

The EU has developed an extensive body of environmental law, complemented by criminal law measures aimed at combating environmental offences ^[5]. Article 83(2) of the Treaty on the Functioning of the European Union (TFEU) permits the establishment of minimum rules concerning the definition of criminal offences where necessary to ensure the effective implementation of EU policies. This provision has enabled the adoption of directives addressing environmental crime.

Despite these developments, existing EU measures remain limited in scope. Environmental offences are often treated as regulatory violations or misdemeanours, attracting relatively mild sanctions. Moreover, EU criminal law largely focuses on harmonization rather than the creation of autonomous EU crimes, resulting in fragmented enforcement across Member States ^[6].

Notably, EU law does not currently recognize environmental destruction as a crime in itself, particularly where such harm is not directly linked to personal gain or specific prohibited activities ^[8]. This creates enforcement gaps and undermines the effectiveness of environmental protection. In light of the scale and complexity of contemporary environmental harm, the current framework appears ill-equipped to address conduct amounting to ecocide.

5. Alternative approaches to addressing ecocide

Several non-criminal approaches have been proposed as alternatives or complements to criminalizing ecocide. One such approach involves recognizing the rights of nature, thereby granting ecosystems legal standing and protection. While this model has gained traction in certain jurisdictions, its effectiveness within the EU legal system remains uncertain.

Other proposals include strengthening corporate due diligence obligations, enhancing environmental impact assessments, and regulating financial institutions to prevent the funding of environmentally harmful projects^[1]. These measures play an important preventive role but are primarily regulatory in nature and may lack the expressive and deterrent force associated with criminal law^[9, 11].

While these approaches are valuable, they do not fully address the moral gravity and systemic nature of ecocide. As such, they should be viewed as complementary rather than substitutive measures. Criminalization remains a necessary component of a comprehensive response to severe environmental harm.

6. Conclusion

This article has examined the case for criminalizing ecocide within the European Union. It has argued that existing EU environmental and criminal law frameworks are fragmented and insufficient to address large-scale environmental destruction. Drawing on philosophical, normative, and human rights-based arguments, it has demonstrated that ecocide constitutes a form of harm warranting the strongest legal condemnation.

The criminalization of ecocide would enhance environmental protection, strengthen accountability, and reinforce the EU's commitment to human rights and sustainable development. By elevating severe environmental destruction to the level of a criminal offence, EU law would acknowledge the gravity of ecological harm and its profound implications for present and future generations.

Nevertheless, the effectiveness of such criminalization depends on the adoption of a clear, comprehensive, and harmonized definition of ecocide. This definition must balance legal certainty with sufficient breadth to capture the diverse forms of large-scale environmental harm. In addition, effective enforcement mechanisms and cooperation among Member States will be essential to ensure that the criminalization of ecocide does not remain merely symbolic.

Ultimately, recognizing ecocide as a crime within EU law would represent a significant step towards addressing the environmental challenges of the twenty-first century. While criminal law alone cannot resolve the ecological crisis, it can play a crucial role within a broader regulatory and normative framework aimed at safeguarding the environment, protecting human rights, and promoting sustainable development.

Disclosure statement

The author declares no conflict of interest.

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The “Cultural Filtering” of AI Guide: Algorithmic Bias and Resistance in Museum Education Space

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Abstract: While AI-guided museum systems are revolutionizing educational experiences, they also pose risks of “cultural filtering.” This paper examines how AI systematically creates and reinforces cultural inequalities through multiple bias mechanisms at the data, algorithm, and application levels. Moving beyond criticism, it proposes a multi-stakeholder resistance framework encompassing algorithmic auditing, interdisciplinary interventions, open-source tools, data rights, and critical literacy cultivation across institutional, technological, and public participation dimensions. The study advocates establishing museum algorithmic ethics standards centered on transparency, inclusivity, cultural sensitivity, and public interest, ensuring technology serves cultural understanding rather than perpetuating biases. This framework provides actionable guidance for building equitable digital-era museum education spaces.

Keywords: AI-guided tours; Cultural filtering; Algorithmic bias; Museum education; Resistance practices; Technological ethics

Online publication: January 30, 2026

1. Introduction

1.1. Research background

1.1.1. Digital transformation of museums as public education spaces

Museums in the 21st century possess immense potential and influence, capable of making the world a better place. Digitalization and accessibility innovations serve as pivotal forces in museum transformation, transforming them into hubs of innovation where new technologies can be fully developed and applied. Digital innovations make museums more accessible and participatory, unlocking greater potential and enhancing social value^[1]. However, such systems have limitations in cultural perception, potentially reinforcing identity stereotypes and sparking controversies like “algorithmic bias” and “cultural representation imbalance.” In designing educational spaces, balancing technological efficiency with cultural diversity has become a core challenge that museums cannot avoid in their digital transformation.

1.1.2. The spread and controversy of AI-guided tours

AI-guided tour technology has rapidly gained traction in global museum education, yet its deep integration has

sparked multifaceted debates. Algorithm-dependent training datasets predominantly originate from mainstream cultural perspectives, posing risks of monopolizing cultural interpretation rights and potentially diminishing the diversity of alternative cultural expressions. Meanwhile, unequal access to technology has created new “cultural participation divides” among elderly populations and low-income groups, while reinforcing implicit biases. Striking a balance between technological innovation and cultural inclusivity has become a central concern for both academia and industry.

1.2. Problem statement

1.2.1. Definition of “cultural filtering”: The implicit screening and reconstruction of cultural content by algorithms

In the context of embedding artificial intelligence into museum education, “cultural filtering” serves as a central critical concept ^[2]. It specifically denotes how algorithms—guided by their design logic, training data biases, and specific cultural values—conduct implicit screening, prioritization, or concealment of multicultural content during data processing, content recommendation, and interpretive processes, ultimately leading to systematic distortion and reshaping of cultural representations. The theories of “algorithmic bias” and “symbolic violence” profoundly influence this concept ^[3–4]. Meanwhile, the increasing use of search engines, news aggregators, and social networks to personalize content through machine learning models may generate “filter bubbles”, where algorithms inadvertently amplify ideological isolation by automatically recommending content individuals might agree with ^[5].

1.2.2. Core contradiction: The claim of technological neutrality and the reproduction of actual cultural prejudice

AI technologies applied in museums are often grounded in the principle of technological neutrality, which maintains that algorithms as tools inherently possess no value orientation. However, specific socio-cultural power structures permeate the design and deployment phases of AI. Research indicates that developers’ cultural assumptions and value preferences are embedded within AI’s algorithmic logic. Not only do these fail to eliminate biases, but they may potentially exacerbate existing cultural prejudices, thereby creating a fundamental contradiction ^[6].

1.3. Research significance

Theoretically, this study extends research on algorithmic bias and fairness from mainstream commercial and social media contexts to public cultural services, aiming to validate and advance existing theoretical frameworks while fostering the development of “critical digital museology.” Practically, it tackles the ethical dilemmas of museum digital transformation by providing actionable ethical evaluation frameworks and inclusive design guidelines for administrators, educators, and technology developers. These efforts help museums uphold their public commitments to diversity, equality, and inclusivity amid technological innovation.

2. Theoretical basis and literature review

2.1. Key theoretical framework

2.1.1. Social Construction of Technology theory (SCOT): AI as a product of cultural politics

The Social Construction of Technology (SCOT) theory challenges technological determinism by proposing core principles such as “interpretive flexibility” (indicating multiple design and interpretive possibilities for new

technologies) and “stabilization” (showing that technological controversies solidify through social negotiation). Additionally, the process of resolution and stabilization involves the gradual reduction of technological disputes through negotiation or power dynamics, allowing a particular design or interpretation to emerge and become entrenched ^[7]. Currently, museum AI applications remain in a contentious phase, with their ultimate form likely shaped by cultural-political dynamics ^[8].

The “cultural filtering” and algorithmic bias in museum AI are manifestations of encoded values within specific groups, not technical failures. SCOT thereby shifts the critical focus from the technology itself to the underlying social forces and cultural power structures, providing a crucial perspective for analyzing how AI impacts cultural inclusivity in museums ^[9].

2.2. Related research fields

2.2.1. Research on algorithmic bias

As an interdisciplinary field integrating computer science, ethics, and sociology, algorithms construct identities and reputations through classification and risk assessment. The absence of transparency, accountability mechanisms, monitoring systems, and due process constraints creates opportunities for discrimination, normalization, and manipulation ^[10]. This study emphasizes that bias is a structural issue inherent to technology, not an accidental malfunction. The mechanisms generating algorithmic bias manifest across multiple dimensions. Data bias refers to historical gaps or stereotypical representations in training datasets.

2.2.2. Technological critique in museology: The shift from “authoritative narratives” to “algorithmic narratives”

Building upon museology’s enduring focus on technological mediation, this study shifts its critical focus from “authoritative narratives” to “algorithmic narratives.” The curatorial-centric “authoritative narrative” is deconstructed by new museology, which identifies the singular linear narrative constructed through artifacts, labels, and spatial arrangements. This deconstruction has given rise to the concepts of “post-museums” and “contact zones”, where pluralistic voices and collaborative knowledge-building emerge ^[11]. Digital technology, once regarded as a tool for realizing this democratization vision, now plays a pivotal role in these developments.

However, these issues are essentially a continuation of the discourse power struggle in museums during the digital era. Within this framework, this study will analyze the challenges and potential resistance brought by “algorithmic narratives” to museum educational spaces.

2.2.3. Resistance theory: Public negotiation and countermeasures on technology

The theory of resistance reveals the public’s agency and creative countermeasures when confronting technological power structures. This study adopts this framework to move beyond the conventional view of passive audience reception, focusing instead on their negotiation and resistance practices in AI-guided interactions. This approach offers new strategies to counter the detrimental effects of cultural filtering.

At its core is resistance theory, which acknowledges the bidirectional nature of power relations: diverse forms of resistance are triggered by dominant forces within subordinate groups. In the technological sphere, the act of “taming” technology serves users to align it with their needs. Regarding interpretive resistance, audiences critically engage with algorithmic content by leveraging their own knowledge systems. When constructing collective counter-narratives, marginalized groups employ collective action to build alternative knowledge systems ^[12].

Under the framework of resistance theory, the audience’s role undergoes a transformation from passive

recipients of “cultural filtering” to active agents of cultural transformation.

3. The “cultural filtering” mechanism in AI-guided tours

3.1. Data layer bias

The cultural understanding of AI-guided tours is constrained by their training data. Current mainstream databases heavily rely on English-language online resources, which inherently carry structural biases. Moreover, the digitization of cultural artifacts is inherently biased—it prioritizes “star collections” and favors tangible objects over living knowledge. These factors collectively create structural gaps in digital archives, resulting in AI models trained on such data being fundamentally knowledge-deficient. This ultimately exacerbates digital cultural inequality within museum spaces and reinforces existing cultural power structures.

3.2. Algorithmic layer bias

3.2.1. Cultural presuppositions in natural language processing

Natural language processing forms the core of AI-generated narration and interactive implementation. Mainstream large language models inherently carry cultural biases, producing content that is not neutral but laden with cultural preferences. This constitutes the key mechanism of “cultural filtering” at the algorithmic level: the narration generated by these models essentially represents an exercise of cultural power. It internally undermines the inclusive education pursued by museums, transforming AI-guided tours from potential cultural bridges into automated enforcers of cultural hegemony.

3.2.2. Application layer bias

At the application level, personalized recommendation systems label multicultural identities through crude user profiles (such as presetting “China tourists must love porcelain”) and combine them with the logic of “heat priority”, directing traffic continuously to a few star exhibits. This transforms recommendation systems from service tools into agents of cultural power, quietly consolidating cultural stereotypes and existing power structures.

4. Integrated resistance framework and algorithmic governance path

4.1. Institutional resistance

Institutional resistance seeks to regulate AI system development and application through institutional frameworks within museums. Key approaches include: implementing algorithmic audits, examining AI systems as cultural artifacts (e.g., the Netherlands National Museum’s transparency in digitalization processes and standards), and the “Museum Algorithmic Justice Alliance” advocating for data cultural representation and museums’ final review authority over AI outputs, transforming their role from “technology consumers” to “critical regulators.” Additionally, forming interdisciplinary curatorial teams to intervene early in technological development, conducting “humanistic proofreading” and “cultural calibration” of AI scripts to construct “second-order narratives.” This institutionalizes diverse humanistic perspectives, asserts cultural interpretive rights, and ensures AI outputs become dialogue-driven outcomes rather than products of technological centralism.

4.2. Technical resistance

4.2.1. Open-source alternative tour guide tools

Open-source community initiatives like MuseoCommons and Open Archive are systematically challenging mainstream business models by building innovative technological ecosystems. Their resistance manifests in three dimensions: First, transparent open-source models and algorithms with publicly accessible training data and code; second, participatory data co-creation where communities collaboratively generate content to ensure diverse origins; third, alternative recommendation algorithms that break the single-minded focus on “engagement.” Despite resource constraints, these projects provide museums with open, democratic, and decolonized technological options and political visions.

4.2.2. Right of data erasure for visitors

Visitors’ right to delete their personal data (as stipulated in Article 17 of the GDPR) constitutes a fundamental form of technical resistance. Exercising this right (such as removing profiling tags like “Asian tourists interested in Chinese porcelain”) can force systems to treat individuals as entirely new objects, thereby weakening the algorithms’ surveillance and classification capabilities. However, in practice, challenges arise, such as museums prioritizing experience over privacy and reliance on third-party systems, complicating the deletion chain. Nevertheless, this right remains a crucial legal lever for resistance ^[13].

4.3. Public participation in resistance

4.3.1. The audience as “citizen auditors”

To address the limitations of traditional feedback mechanisms in detecting algorithmic cultural misinterpretations, an AI-guided tour system can incorporate a crowdsourced “bias labeling” and feedback mechanism. When users identify inappropriate content, they can immediately report it via dedicated in-app buttons (e.g., “Mark Bias”), generating a “bias heatmap.” After expert review, corrected content is fed back into the model, forming a closed-loop system of “feedback—review—retraining.” This approach challenges the monopoly of technical experts on cultural interpretation rights, but must be integrated with expert review mechanisms to prevent inaccurate or malicious feedback ^[14].

4.3.2. Developing critical digital literacy

Through educational programs, museums cultivate critical digital literacy in the public, serving as their most forward-looking and fundamental form of resistance. The goal is to equip the public with “algorithmic immunity”, enabling them to instinctively raise critical questions when interacting with AI systems—such as “Whose perspective does this narrative represent? Whose viewpoint is being overlooked?” Once audiences begin habitually pondering these questions, any attempt at “cultural filtering” will be exposed to critical scrutiny. This forms the cornerstone for museums to fulfill their public mission and build a reflective digital society ^[15].

4.4. Algorithmic governance path for multi-party collaboration

Effective algorithm governance requires establishing a collaborative framework involving technology developers, museum administrators, cultural researchers, and the public. Each party must assume clear responsibilities: Technology developers should ensure system transparency and auditability, while providing interpretable interfaces and “backdoors” for human intervention. Museum administrators need to shift from passive procurement to proactive curation, establish ethical standards, and institutionalize operational feedback mechanisms. Cultural

researchers should provide decolonized interpretations and independent evaluations. The public must transform into “citizen auditors”, exercising data rights and participating in bias monitoring. At the core of this collaborative system is the establishment of a “Joint Algorithm Ethics Committee” with substantive oversight authority. Through regular reviews of system operations, dispute resolution, and guideline updates, this framework transforms fragmented efforts to combat algorithmic bias into sustainable public cultural practices.

4.5. Future research directions

Future research should focus on two key directions. First, it should move beyond Eurocentric perspectives to conduct in-depth comparative studies of non-Western museums’ localization practices. For instance, examining the indigenous knowledge annotation in South Africa’s Iziko Museum Cluster and the cultural semantic network construction at the Dunhuang Academy can reveal the essence of “ethical AI” as a multicultural practice. Second, an integrated framework should be adopted to analyze how algorithmic biases and physical space biases (such as colonial architectural layouts) reinforce each other. This approach would explore AI’s potential as a “corrective tool” to promote spatial justice through “digital shortcuts” or “counter-narrative pathways”, advancing research from “algorithmic correction” to “co-design of space-algorithm synergy.”

5. Summary

This study reveals the “cultural filtering” mechanism formed by AI-guided tours in museum spaces, rooted in structural imbalances in training data, algorithmic epistemology with Western-centric biases, and commercial logic. This mechanism reduces multicultural practices to a singular narrative, posing a threat to the democratization of public knowledge.

This paper demonstrates that biases can be effectively addressed and reshaped through institutional, technical, and participatory resistance practices. Multiple stakeholders can guide technology toward public ethics via algorithmic audits, interdisciplinary collaboration, open-source tools, data rights, and literacy education. The museum industry must move beyond fragmented technological applications and remedial measures to collectively establish clear and binding technical ethics guidelines for the algorithmic era.

Looking ahead, museums should take the lead in practicing “ethical AI” rather than being passive consumers of technology. They must serve as exemplary spaces where algorithms, guided by critical human wisdom, deepen cultural understanding rather than solidify cultural biases.

Disclosure statement

The authors declare no conflict of interest.

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A Study on the Spatial Distribution Characteristics and Influencing Factors of Traditional Villages in Jiangxi Province

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Abstract: This study selects 413 national-level traditional villages in Jiangxi Province as research objects. Based on the ArcGIS 10.8 software and combined with mathematical statistics methods, it conducts an in-depth investigation into the spatial distribution pattern of traditional villages and their influencing factors. The research results show that the overall spatial characteristics of traditional villages in Jiangxi Province present a “scattered but clustered” feature, distributed in strip or point patterns along plain areas. Notably, traditional villages in Ji’an City and Fuzhou City exhibit obvious agglomeration phenomena. According to the analysis data, approximately 82.8% of village locations have significant riparian characteristics, reflecting the ancestors’ survival wisdom of “choosing water to settle.” Further analysis reveals that topography and hydrological environment serve as the physical basis constraining village location selection, while diverse cultures such as Huizhou culture, Linchuan culture, Luling culture, and Hakka culture deeply shape the spatial layout of villages. Furthermore, cultural factors and hydrological factors interactively act together to constitute the key composite driving mechanism influencing the spatial layout of traditional villages in Jiangxi Province.

Keywords: Jiangxi Province; Traditional villages; Spatial distribution; Distribution characteristics

Online publication: January 30, 2026

1. Introduction

Traditional villages refer to settlements that have a long history, rich traditional resources, and possess significant historical, cultural, scientific, artistic, social, and economic values, which warrant protection^[1]. With the acceleration of urbanization, blind tourism development and new rural construction often lead to varying degrees of damage to these traditional villages. In the process of solving the “three rural issues”, the three elements—architecture, ecology, and culture—carried by traditional villages hold irreplaceable and important positions. In 2023, the sixth batch of the National List of Traditional Villages added 1,336 villages nationwide, including

70 new ones in Jiangxi Province. To date, a cumulative total of 8,155 traditional villages have been officially announced across six batches. This paper selects 413 national-level traditional villages from Jiangxi's six batches as research subjects. It employs ArcGIS 10.8 combined with quantitative statistical methods to analyze their spatial distribution characteristics and explore their influencing factors.

2. Study area and data sources

2.1. Study area

Jiangxi Province is located in the southeast of China. Geographically, it is characterized by a terrain dominated by mountains and hills, with a distinct topography that slopes from high in the south to low in the north (**Figure 1**). The total area of the province amounts to approximately 166,900 square kilometers, and its permanent population stands at roughly 45.02 million people. Administratively, it consists of 11 prefecture-level cities and 100 counties (cities and districts).

The province features a well-developed water system with dense river networks, centered around Poyang Lake. This extensive hydrological network is primarily formed by the convergence of five major river systems: Ganjiang, Fuhe, Xiushui, Raohe, and Xinjiang^[2]. Climatically, Jiangxi belongs to the typical subtropical monsoon climate, characterized by humidity, abundant rainfall, distinct seasons, and complex weather changes.

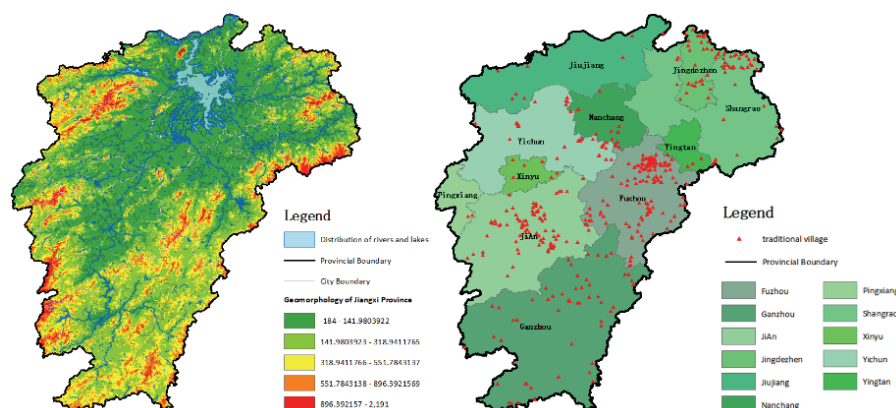


Figure 1. Topography, landforms, and distribution of traditional villages in Jiangxi Province

2.2. Data sources

The data foundation of this study primarily stems from the following platforms: the list of national traditional villages in Jiangxi Province was sourced from the Traditional Villages Network; geographic coordinates were obtained via Baidu Maps and converted into WGS1984 format before being imported into ArcGIS 10.8; terrain elevation data utilized a 30 m precision DEM image provided by the Geospatial Data Cloud; administrative boundary and landform type data were acquired from the Resource and Environment Science Data Center of the Chinese Academy of Sciences.

3. Spatial distribution characteristics of traditional villages in Jiangxi Province

3.1. Spatial distribution type

To determine the spatial distribution type of traditional villages, it is first necessary to identify their belonging

spatial elements. Spatial elements include point elements, line elements, and surface elements. Among these, point elements can be categorized into three types: uniform distribution type, random distribution type, and aggregated distribution type^[3].

By using software and combining relevant data to calculate $R = 0.7426$, it can be roughly judged that the spatial distribution type of traditional villages in Jiangxi Province is a cohesive distribution type, with small clusters present.

3.2. Spatial distribution balance and aggregation area

From the traditional village distribution map, it can be observed that their distribution has a certain degree of imbalance, which can be supported by the imbalance index as an indicator. The imbalance index can reflect the degree of balance in the distribution of research objects within the research area^[4].

By organizing and calculating relevant data, $S=0.689$ was obtained, indicating a significant imbalance in the distribution of traditional villages in Jiangxi Province. From the Lorenz curve, it can be seen that the number of traditional villages in Fuzhou City ranks first with a proportion of 32.69%, followed closely by Ji'an City with a proportion of 20.34% (**Figure 2**). Ganzhou City ranks third with a proportion of 13.32%, while Shangrao City is only 2.91% lower than it. The proportion of traditional villages in Pingxiang City is the lowest, only 0.48%, which is less than one-tenth of that of Fuzhou City, which ranks first.

According to the nuclear density analysis map of traditional villages, the layout of villages in the province presents a significant feature of “large dispersion and small aggregation” (**Figure 3**). Specifically, the central part of Ji'an City, the northern part of Fuzhou City, as well as the northern parts of Jingdezhen and Shangrao City, constitute a high-density core gathering area, while the remaining vast areas exhibit a low-density discrete distribution state.

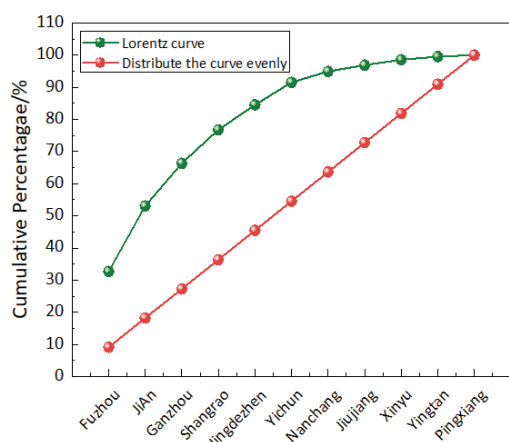


Figure 2. Lorenz Curve of traditional villages in Jiangxi Province

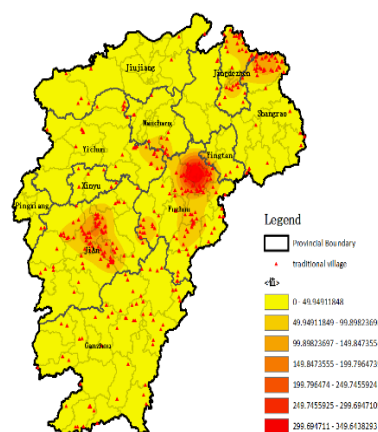


Figure 3. Nuclear density analysis of traditional villages in Jiangxi Province

4. Exploration of factors influencing distribution

4.1. Terrain factors

The geomorphic types of Jiangxi Province are mainly hills (42%) and mountains (36%) (**Figure 4**). The main

mountains are distributed along the border of Jiangxi Province, bordering Huaiyu Mountain in the northeast, Mount Wuyi in the east, Dayu Mountain and Jiulian Mountain in the south, Luoxiao Mountain in the west, Mufu Mountain and Jiuling Mountain in the northwest^[5].

According to the topographic map of Jiangxi Province, most traditional villages in Jiangxi Province are distributed in plain areas (**Figure 5**). The flat terrain, fertile soil, and abundant water resources in plain areas greatly facilitate the development of agricultural life, laying the foundation for the steady development of traditional villages over a long history.

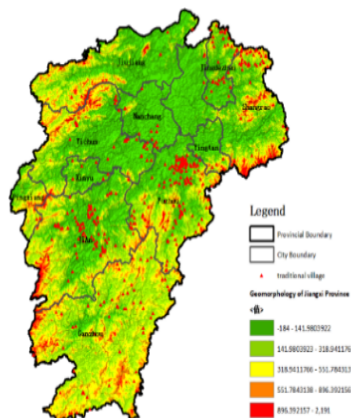


Figure 4. Distribution and geomorphic map of traditional villages

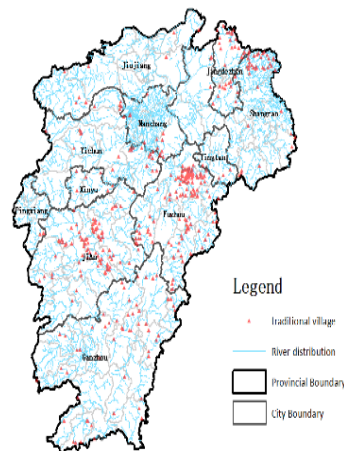


Figure 5. Water system relationship map of traditional villages

4.2. Hydrologic factors

Jiangxi Province has a huge water network system centered around Poyang Lake, consisting of five major water systems: Gan River, Fu River, Xiu River, Rao River, and Xin River^[6]. Among them, the Gan River is known as the “Golden Waterway.” These five major water systems run through the entire province, not only connecting various parts of Jiangxi, but also radiating to surrounding areas, forming an economically developed and culturally interconnected watershed pattern.

From the above figure, it can be seen that the spatial distribution of traditional villages in Jiangxi Province exhibits a significant characteristic of living by water. Using a distance of 1km as a water system buffer zone, the total number of traditional villages located within the buffer zone is 342, accounting for 82.8% of the total. This indicates that the distribution of traditional villages is closely related to rivers. Among them, the majority of traditional villages are located within the buffer zones of the Ganjiang River Basin and Fuhe River Basin.

4.3. Cultural factors

Based on geographical divisions, Jiangxi Province is typically categorized into four distinct regions: Northeastern, Central, Western, and Southern Jiangxi^[7]. This study utilizes these four major divisions as a framework to investigate regional cultural characteristics and further examines the correlation between geographical features and cultural factors.

According to relevant studies, traditional villages in Jiangxi Province are primarily concentrated in the central region, exhibiting significant differences in cultural zoning. As an essential chapter of “Gan Culture”, Linchuan

Culture centers on the central part of Fuzhou City, forming a high-density cluster of traditional villages^[8]. These settlements not only carry the profound heritage of the “Hometown of Scholars” but also preserve the large-scale historical architecture of the Gan School.

Influenced by the profound heritage of the Luling culture, the region of Ji'an has not only nurtured historical figures such as Ouyang Xiu and Wen Tianxiang, but also preserved numerous precious traditional villages in its urban-rural fabric. These villages are not only the quintessence of Jiangxi architecture, but also three-dimensional carriers of the “Unity of Heaven and Humanity” philosophy held by ancient Jiangxi people, perfectly integrating clan systems, gongdu culture, and fengshui theory within the landscape. The distribution of traditional villages in Ji'an exhibits distinct geographical and cultural characteristics. Relying on the water transport advantages of the Ganjiang River basin and the natural environment of the mountains surrounding the water, a unique cluster of villages has formed. Meibei Ancient Village, located in Wenshi Town, Qingyuan District of Ji'an City, sits by the Fu River. As a representative historical and cultural village, it holds the reputation of “The First Village of Luling Culture.”^[9]. As a typical example of the Jiangyou ethnic group's ancient village, Meibei relies on mountains and water, with architectural styles primarily based on the Ming and Qing dynasties, skillfully blending the styles of academies, ancestral halls, and religious buildings. Yanfang Ancient Village is situated in Jintan Town, Jishui County, neighboring the Ganjiang River and backed by Long Mountain.

The northern part of Shangrao City and Jingdezhen City, located at the northeastern corner of Jiangxi Province and the border between Anhui and Jiangxi, represent a transitional geographical zone. Culturally, this area is known as a “Hui Culture Enclave.” Historically centered on Wuyuan, the region has been deeply influenced by the New An Confucianism and Huizhou merchant culture. Spatial analysis using ArcGIS reveals a significant clustering pattern. Traditional villages in this area typically follow the Feng Shui philosophy of “resting against mountains, encircling water, and facing screens”, forming a “core-dense, periphery-sparse” structure distributed in a belt-like pattern along basins and river valleys. These villages are not merely residential spaces but living museums of intangible culture. Yan Village, often referred to as the “Great View Garden” of Huizhou architecture, preserves a large number of complete ancestral halls, residences, and ancient bridges from the Ming and Qing dynasties. It serves as an important physical carrier for studying the Huizhou merchants' philosophy of “accumulating wealth and seeking blessings.”

Situated at the intersection of Jiangxi, Guangdong, and Fujian provinces, the Gannan region features a landscape dominated by hills and mountains, characterized by sparse and scattered water systems. Due to late economic development and inconvenient transportation, traditional villages in Ganzhou have long remained in a state of low human disturbance, preserving the authentic appearance of Ming and Qing dynasty architecture. To cope with complex terrain and historical interpersonal conflicts, the Hakka people developed distinctive walled enclosures. Isolated by mountainous barriers, these areas became “islands” where Central Plain Han culture retained its unique form. Bai Lu Village in Gangxian is hailed as a “National Historic and Cultural Village”, serving as one of the best-preserved ancient Hakka settlements in southern Jiangxi, centered around its ancestral hall complex and showcasing the typical style of Hakka manor-style dwellings^[10].

5. Conclusion

Based on the aforementioned analysis, a quantitative assessment was conducted regarding the geographical distribution of 413 nationally recognized traditional villages across six batches in Jiangxi Province. By examining

three dimensions, this study analyzed the spatial configuration of these villages and systematically explored the influencing factors, leading to the following conclusions:

Spatial Pattern: Calculations of the nearest neighbor index confirmed that the spatial distribution type is characterized as cohesive clustering. High-density zones are primarily concentrated in Ji'an City, Fuzhou City, the northern region of Shangrao City, and Jingdezhen City. However, an overall uneven distribution persists, exhibiting the distinct feature of “large-scale dispersion with localized aggregation.”

Influencing Factors: The distribution is significantly influenced by natural environmental factors, predominantly situated in flat plains or gentle hilly areas. A positive correlation exists between village distribution and elevation. Furthermore, the vast majority of villages are closely associated with water systems. The combined influence of hydrological and cultural factors exerts a cumulative effect, ultimately promoting optimal site selection.

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Author contributions

Yunyang Zheng conceived the idea of the study. Xingyu Liu and Jiayao Zhu performed the experiments. Junqing Deng analyzed the data and wrote the paper.

Disclosure statement

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Application and Analysis of Big Data Mining in Health Management of Chronic Diseases Based on the Internet of Things

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Abstract: Objective: To analyze the application effects of big data mining in the health management of chronic diseases under the premise of the Internet of Things (IoT). Methods: A total of 188 high-risk individuals with chronic diseases in the jurisdiction from January 2022 to January 2024 were selected and evenly divided using a random number table. The observation group underwent big data mining management under the premise of IoT, while the reference group received conventional health management. The management effects of the two groups were compared. Results: The management indicators of the observation group were superior to those of the reference group. After management, the self-management ability scores of the observation group were higher than those of the reference group, the psychological status scores were lower than those of the reference group, and the management satisfaction was higher than that of the reference group ($P < 0.05$). Conclusion: Implementing big data mining management under the premise of IoT for high-risk individuals with chronic diseases can improve their file establishment rate, as well as the rates of early warning and screening for chronic diseases. It can also enhance the self-management ability of high-risk individuals, correct their adverse psychological conditions, and achieve high management satisfaction.

Keywords: Internet of Things; Health management of chronic diseases; Big data mining; Self-management ability; Management satisfaction

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1. Introduction

Chronic diseases are highly prevalent among middle-aged and elderly populations. Due to multiple factors such as changes in lifestyle and adjustments in dietary patterns, the onset age of chronic diseases is increasingly becoming younger, posing a significant threat to residents' health^[1]. At the current stage, in the health management process for chronic diseases, information technology is actively introduced to achieve scientific and precise management, thereby improving disease prognosis. In this context, the Internet of Things (IoT) and health big data have emerged

as novel means for preventing and treating chronic diseases. Continuous tracking can be achieved through services such as remote diagnosis, treatment, and follow-up management, thereby enhancing the quality of management. Under the premise of IoT, big data mining can effectively organize complex data on high-risk individuals, fully uncover hidden information, summarize scientific evidence, and subsequently carry out comprehensive health management for chronic diseases throughout the entire process, elevating their prevention and treatment standards^[2]. Based on this, this study selected 188 high-risk individuals for chronic diseases to evaluate the health management effects of big data mining under the premise of IoT.

2. Materials and methods

2.1. General information

A total of 188 high-risk individuals for chronic diseases within the jurisdiction from January 2022 to January 2024 were selected and evenly divided using a random number table. The observation group consisted of 94 cases, including 52 males and 42 females, aged between 40 and 84 years old, with an average age of 56.45 ± 3.67 years. The reference group consisted of 94 cases, including 50 males and 44 females, aged between 41 and 86 years old, with an average age of 56.71 ± 3.52 years. There were no significant differences in the data between the two groups ($P > 0.05$).

Inclusion criteria: Identified as high-risk for chronic diseases during health check-ups or hospital admissions; adults; with an educational level of junior high school or above; proficient in using smartphones; with complete basic information; informed about and consenting to the study. Exclusion criteria: Accompanied by severe acute illnesses; with malignant tumors; abnormal language communication or cognitive abilities; suffering from mental disorders; withdrawing from the study midway.

2.2. Methods

The reference group underwent routine health management: Weekly knowledge lectures were organized by the hospital's outpatient department, where chronic disease educational pamphlets were distributed on-site. Chronic disease experts served as the main speakers, providing detailed explanations of disease knowledge, demonstrating self-management essentials, and informing about daily life precautions. Hospital nursing staff conducted monthly follow-up services for high-risk individuals, primarily through telephone calls, to dynamically assess their off-site management situations.

The observation group underwent big data mining management under the premise of the Internet of Things (IoT): (1) Introduction of Internet technology: The hospital's information management system was connected to community health management platforms and multi-level hospital management systems to achieve data sharing. In-depth mining of big data was conducted, enabling the IoT platform to connect with wearable medical devices or mobile internet devices. Big data was processed in an isomorphic manner through data heterogeneity, and the high-risk individuals' data, after secondary mining and processing, was statistically analyzed using the HBase database and Hadoop system framework to obtain information such as disease diagnosis results, disease progression prediction curves, and health management content. This information was then transmitted to the doctors' end, facilitating a comprehensive understanding of the high-risk individuals' chronic disease onset risks and development trends. (2) Integrated Information Network for Medical Consortia: Integrate resources within the medical consortium, such as chronic disease equipment management and health datasets, to establish an in-hospital

cloud management platform for chronic diseases. Regularly collect health status, disease diagnosis, and treatment, and healthcare information from high-risk individuals, evaluate their chronic disease management throughout the entire process, screen for risk factors in a targeted manner, and accordingly refine health management plans.

(3) Combination of Online and Offline Approaches: Establish a WeChat public account for chronic disease health management and invite high-risk individuals to follow it. The public account features modules such as appointment scheduling for chronic disease check-ups and a health knowledge column. The appointment scheduling module displays information about the attending doctors' qualifications and allows for appointments to be made up to one week in advance. Three days before a follow-up visit, the WeChat public account automatically sends reminder messages, enabling high-risk individuals to make online appointments and regularly undergo chronic disease check-ups. The health knowledge column covers various aspects, including disease knowledge, treatment plans, self-monitoring, key points for daily life management, and emergency response measures. Each section includes links to articles with relevant knowledge, allowing high-risk individuals to flexibly select and learn about disease-related information. The public account sends weekly updates to high-risk individuals on sleep knowledge, healthy eating knowledge, or exercise knowledge, such as healthy recipes, sleep improvement techniques, and key points for practicing Tai Chi or yoga, encouraging them to actively learn self-management knowledge. Distribute medication knowledge to high-risk individuals through private WeChat chats, covering dosage and administration, proper storage methods, identification, and management of adverse reactions, etc. This information can be conveyed through graphic materials, animated videos, and other formats. Send mental health knowledge 2–3 times a week, utilizing animations to demonstrate meditation training techniques and mindfulness-based stress reduction methods, encouraging high-risk individuals to engage in emotional management. Organize offline expert consultation activities once a month at the outpatient department to thoroughly assess the chronic disease conditions of high-risk individuals and provide treatment recommendations from experts.

2.3. Observation indicators

Management Indicators: Evaluate the file establishment rate for high-risk populations, the rate of chronic disease early warning and screening, and other relevant indicators.

Self-Management Ability: Utilize the Health-Promoting Lifestyle Profile II (HPLP II), which includes dimensions such as health responsibility (9 items), exercise (8 items), interpersonal relations (9 items), self-actualization (9 items), nutrition (9 items), and stress management (9 items). Each item is scored from 1 to 4, with higher scores indicating better self-management ability.

Psychological Status: (1) The Mishel Uncertainty in Illness Scale-Adult (MUIS-A), consisting of 28 items, each scored from 1 to 5, with higher scores indicating greater uncertainty in illness. (2) The Self-Perceived Burden Scale (SPBS), comprising 10 items, each scored from 1 to 5, with higher scores indicating a greater sense of self-perceived burden.

Management satisfaction: A self-developed management satisfaction scale was used, encompassing communication frequency, individual guidance, etc., with a total score of 100 points. Scores exceeding 80 indicate high satisfaction, scores between 40 and 80 indicate basic satisfaction, and scores below 40 indicate dissatisfaction.

2.4. Statistical analysis

Data were processed using SPSS 28.0 software. Measurement values were compared/tested using t-values, and count values were compared/tested using chi-square (χ^2) values. Statistical significance was set at $P < 0.05$.

3. Results

3.1. Comparison of management indicators between the two groups

The observation group had higher rates of establishing files for high-risk populations, early warning for chronic diseases, and early screening compared to the reference group ($P < 0.05$) (Table 1).

Table 1. Comparison of management indicators between the two groups [n/%]

Group	Number of Cases (n)	Health Record Establishment Rate	Chronic Disease Early Warning and Screening Rate
Observation Group	94	92 (97.87)	91 (96.81)
Control Group	94	84 (89.36)	84 (89.36)
χ^2 -value	-	5.697	4.049
P -value	-	0.017	0.044

3.2. Comparison of self-management abilities between the two groups

The observation group scored higher in self-management ability after management compared to the reference group ($P < 0.05$) (Table 2).

Table 2. Comparison of self-management abilities between the two groups (Mean \pm SD, points)

Group	Number of Cases (n)	Health Responsibility		Physical Exercise		Interpersonal Relationships	
		Pre-management	Post-management	Pre-management	Post-management	Pre-management	Post-management
Observation Group	94	20.15 \pm 2.97	31.75 \pm 3.19	16.87 \pm 3.18	27.15 \pm 3.52	19.78 \pm 3.11	30.47 \pm 3.61
Control Group	94	20.19 \pm 3.04	28.01 \pm 3.11	16.58 \pm 3.23	24.51 \pm 3.60	19.83 \pm 3.15	27.16 \pm 3.55
t-value	-	0.091	8.139	0.620	5.084	0.110	6.338
P -value	-	0.927	0.000	0.536	0.000	0.913	0.000

Group	Number of Cases (n)	Self-Actualization		Nutrition		Stress Management	
		Pre-management	Post-management	Pre-management	Post-management	Pre-management	Post-management
Observation Group	94	17.65 \pm 3.15	29.87 \pm 3.77	18.56 \pm 3.04	30.11 \pm 3.53	20.13 \pm 3.11	31.25 \pm 3.19
Control Group	94	17.61 \pm 3.20	26.04 \pm 3.71	18.59 \pm 3.06	27.05 \pm 3.42	20.19 \pm 3.14	28.01 \pm 3.14
t-value	-	0.086	7.020	0.067	6.036	0.132	7.018
P -value	-	0.931	0.000	0.946	0.000	0.895	0.000

3.3. Comparison of psychological status between the two groups

The observation group scored lower in psychological status after management compared to the reference group ($P < 0.05$) (Table 3).

Table 3. Comparison of psychological status between the two groups (Mean \pm SD, points)

Group	Number of Cases (n)	MUIS-A (Uncertainty in Illness)		SPBS (Social Phobia)	
		Pre-management	Post-management	Pre-management	Post-management
Observation Group	94	92.16 \pm 5.78	60.19 \pm 4.14	41.69 \pm 5.06	26.70 \pm 3.11
Control Group	94	92.23 \pm 5.72	71.38 \pm 4.20	41.73 \pm 5.09	30.29 \pm 3.78
t-value	-	0.083	18.396	0.054	7.111
P-value	-	0.934	0.000	0.957	0.000

3.4. Comparison of management satisfaction between the two groups

The management satisfaction in the observation group was higher than that in the reference group ($P < 0.05$) (Table 4).

Table 4. Comparison of management satisfaction between the two groups [n/%]

Group	Number of Cases (n)	Very Satisfied	Satisfied	Dissatisfied	Overall Satisfaction Rate
Observation Group	94	62 (65.96)	30 (31.91)	2 (2.13)	97.87 (92/94)
Control Group	94	57 (60.64)	27 (28.72)	10 (10.64)	89.36 (84/94)
χ^2 -value	-	-	-	-	5.697
P-value	-	-	-	-	0.017

4. Discussion

China has a large population and vast territory, with a significant number of patients suffering from chronic diseases. The difficulty in health management poses an urgent public health issue that needs to be addressed ^[3]. At present, China is actively promoting a prevention and control system for chronic diseases and issuing relevant clinical guidelines. Non-invasive examinations and other means can be utilized to screen individuals at high risk for chronic diseases, providing targeted and proactive interventions to reduce the incidence of chronic diseases. However, the lack of awareness among high-risk individuals about their own conditions, inadequate coordination and cooperation among hospitals at all levels, and low participation from the entire society make it difficult to efficiently implement health management for chronic diseases ^[4]. Based on this, Internet of Things (IoT) technology has gradually emerged as a novel approach for chronic disease management. With its networked and digital characteristics, it can comprehensively aggregate health big data, enable resource sharing, and thereby improve the quality of health management.

IoT technology can efficiently connect multiple internet information points, dynamically assess the chronic disease status of high-risk individuals, enable early detection and treatment, and thus prevent chronic diseases. Big data mining, supported by IoT technology, can interconnect disease prevention systems within and between hospitals, share network resources while ensuring network security, and establish a cloud management platform for efficient health management of chronic diseases ^[5].

The results indicated that the observation group had higher rates of establishing health records for high-risk populations, rates of chronic disease early warning and screening, and scores for self-management ability compared to the reference group. Additionally, the psychological status scores were lower, and management

satisfaction was higher in the observation group than in the reference group ($P < 0.05$). The analysis of the reasons is as follows: The Internet of Things (IoT) places chronic disease health management at its core, fully leveraging big data information to establish a big data management system. This system is capable of collecting and analyzing high-risk individual data through multiple channels and formats, integrating disordered and scattered data resources, and visually displaying data analysis results through software programming and other technologies. Based on this premise, management plans can be formulated to ensure management timeliness^[6-7]. The IoT technology can aggregate high-risk individual data using specialized information networks and the internet as network carriers. Big data mining can then perform isomorphic processing on this data, followed by statistical analysis using data mining systems. The above process enables the collection, processing, and transmission of high-risk individual data resources, allowing for long-term storage. It possesses interconnected and intelligent characteristics, enabling dynamic tracking of chronic disease conditions in high-risk individuals, as well as intelligent identification and behavioral monitoring functions, thereby facilitating continuous management of high-risk individuals with chronic diseases^[8]. Under the premise of IoT and big data mining, a combined online and offline management model for high-risk individuals can effectively guide their lifestyle and medication behaviors. Leveraging the flexibility and interactivity of WeChat official accounts, it enhances communication between nurses and patients, thereby improving management satisfaction among high-risk individuals^[9]. The aforementioned management approach demonstrates high feasibility. It pays close attention to the disease conditions of high-risk individuals and provides psychological counseling to them, continuously cultivating their self-management abilities and enabling them to actively regulate their psychological states. Consequently, it yields favorable management outcomes^[10].

In summary, under the premise of the Internet of Things (IoT), big data mining management can enhance the self-management capabilities and psychological well-being of individuals at high risk for chronic diseases. It encourages them to establish standardized health records and undergo regular disease screenings, thereby garnering a high level of management acceptance.

Disclosure statement

The author declares no conflict of interest.

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Globalization and Its Impact on the Fashion Industry

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Abstract: This report delves into the multifaceted impact of globalization on the fashion industry, focusing on its supply chain dynamics and strategic implications. Globalization, a prominent phenomenon since the 1980s, is characterized by the cross-border flow of goods, capital, and various socio-economic elements, shaping a complex and interconnected world. Within this context, the fashion industry undergoes significant transformations driven by the globalization process. The fashion industry, in particular, experiences both favorable and adverse effects of globalization. The report explores these impacts, emphasizing the growing accessibility of fashion trends due to advancements in social media, advertising, and other communication channels. This enhanced accessibility fosters the creation of individual preferences and unique styles, blending global and personal aesthetics. However, globalization also brings challenges like economic disparities and cultural homogenization within the fashion industry. Finally, the report highlights the intricate relationship between globalization and the fashion industry, emphasizing the need for understanding the complex commodity chain and the impact of corporate power on this dynamic sector.

Keywords: Globalization; Supply chain; Commodity chain

Online publication: January 30, 2026

1. Introduction

This report will try to illustrate, through the use of the fashion industry, an understanding of the impact of globalization and corporate power on economic change. This impact will be discussed through three key issues: 1. the increasingly complex, globalized, and industrialized commodity chain; 2. the increasing control of powerful corporate players; and 3. implications to the fashion industry.

2. Literature review

2.1. The definition of “globalization”

Globalization is a phenomenon of increasing prominence, especially since the 1980s, and it forms a basic

characteristic of the current era. The definition of globalization is not unified, generally speaking, but from the materialistic form perspective; globalization is the cross-border flow of goods and capital ^[1]. This development consists of several stages, from transnational to local internationalization and globalization. The cross-border flow of goods and capital constitutes the original form of globalization. Throughout this process, the corresponding regional and international economic management organizations and economic entities, as well as the culture, lifestyle, values, and ideologies, spiritual power of transnational communication, collide, conflict, and fuse. Taking the fashion industry as an example, globalization is the economic and social process whereby local markets and cultures are increasingly dominated by the global market and cultures ^[2].

Overall, globalization—taking economic globalization as its core—assimilates various countries and ethnic regions as well as elements of politics, culture, science and technology, military, security, ideologies, lifestyles, and values, within a multi-level and multi-field related process influencing and restricting them from a pluralistic concept. “Globalization” can be summarized into ten aspects: science and technology, economy, politics, law, management, organization, culture, concept, interpersonal, and international relations.

2.2. Possible impacts of “globalization”

The possible impact brought about by the globalization includes: Global growth; a number of common criteria, such as copyright law; the growth of international trade being faster than the world’s economic growth; greater control by multinational corporations with regard to shares within the world’s economic growth; the development of the global financial system and terrorism within globalization, and the involvement of terrorist attacks and terrorism organizations many times not in their own actions, and has nothing to do with their own. Many of these are supported by various organizations that are positive about globalization and, in many cases, by the government and other people actively promoting globalization. The reason behind this is an economic theory, which states that this kind of comparative advantage with free trade can make resource allocation more efficient for both sides involved in the trade ^[3].

After the Second World War, many international organizations, such as the General Agreement on Tariffs and Trade (GATT), greatly reduced established international trading barriers between nations. The greatest difference came with the World Trade Organization (WTO), which also evolved from the GATT. The main aims of this organization were divided into two parts: Firstly, it should promote free trade. In accomplishing this task, it required improvements within three different aspects: with regard to commodities, every country should have fewer tariffs or eliminate tariffs altogether, and should also try to establish a free trade zone to reduce tariffs ^[4]. In terms of capital, governments should reduce or eliminate capital controls, as capital controls affect the development of trade ^[5]. Finally, local governments should reduce and eliminate subsidies for local industry to achieve fairer market circumstances.

When the impacts of globalization are applied to the fashion industry, it might be seen to affect the industry slightly differently from that of other industries, as fashion is increasingly becoming a more dominant force. Additionally, globalization has a significant effect on an individual’s choice of clothing and personal style, whether it is work-related or casual ^[6]. Like the impacts mentioned above, globalization can also have favorable impacts and adverse impacts on this particular industry. The favorable impacts of globalization upon the fashion industry could be shown in the growing accessibility of the latest fashion trends and the creation of individual preferences. Indeed, higher accessibility makes the trend more readily available, thanks to the outburst of numerous and massive social networks and blogs, and various ways of advertising, such as magazines, music videos, films,

the internet, and television, among others. The creation of individual preference could also be regarded as the combination of personal, more unique styles and global styles.

2.3. The definition of “commodity” and “commodity chain”

This report will examine the increasing complexity of supply chains within the clothing industry, though key terms like “commodity” and “global commodity chain” have to be defined first. Within Marxist political economics, a “commodity” is defined as a “product could be exchanged” ^[7]. However, along with the development of the economy, many natural resources and non-labor products also entered the exchange arena. Thus, modern economists, building on the basis of the original definition of “product” and extension, have devised a more generalized definition of commodity, which is used to exchange the use value of “goods” ^[8]. Global commodity chains were first put forward by Duke University. While researching commodity chains, he provided a systematic analysis, explaining global consumption, the production of the world economy trade, and the industrial upgrading of industrial geographic research. Additionally, he assessed the Global Value Chain (GVC) to see how products within the process improved the status of competition within the global production and marketing system, using “driven by producer” (producer-driven) or “driven by the buyer” (buyer-driven) models to explore industry within the structure of the state, and assisting developing nations in terms of product upgrades. This research will focus on the earliest garment-processing industry, but also contains a small number of more recent studies to apply this concept to agricultural geography research.

Within global commodity chains, there are two kinds of management structure: producer-driven and buyer-driven commodity chains. Gereffi refers to the so-called producer-driven commodity chains, that is, big manufacturers’ links through the forward- and backward-production processes and by the content of the related industries to provide standardization, distribution, and service to control an entire production system ^[9]. In contrast, the initiative in buyer-driven commodity chains speaks to larger retailers, trading companies, and brands. With regard to famous brands with strong guidance, the pathways of their scattered big buyers use design and management of international production networks—especially in the third world—to specify their production projects. Buyer-driven commodity chains for profit are not the same as producer-driven commodity chains in terms of scale, quantity, and technical benefits. Indeed, it is from their high value of research, design, sales, marketing, and financial services—in a unique combination—which makes retailers and brand marketers and brand manufacturers in overseas factories come together, and the connections between main products in a consumer market become a niche strategy of action. In producer-driven and buyer-driven commodity chains, vendors are led to produce different kinds of “royalty” to establish barriers to entry for new companies. These royalties may be substantial (such as new products or technologies), fuzzy (brand, reputation, and experience), or somewhere within network marketing skills (buyers). With regard to the issue of industrial upgrading, questions about royalty lie in the creation of the royalty and protection, because the organization creates the royalty by creating a mechanism, through the production of goods and services. Here, royalty is seen to be an additional value, economic upgrading, and satisfaction naturally increases the additional value of creation and protection ability; and to achieve this goal, it should be improved through industrial competitiveness. There are many ways to produce additional value, such as technical innovation to brand creation, from economies of scale to flexible specialization, from low-cost to high-value ^[10].

The characteristics of two different chains could be seen in different types of industry. For example, producer-driven commodity chains can usually be found in industries with the following characteristics: Global

commodity chains consist of large, often transnational enterprises that coordinate production systems, including their “upstream” and “downstream” elements within the center of their roles ^[11]. For example, the automobile, semiconductor, aviation, and motors sectors are especially obvious with regard to capital and technology-intensive industries. The geographical distribution of these industries is often transnational, and within their commodity chains, the number and distribution of their development degree remain different. The original components of international outsourcing, within many competing strategies in the league in the world, remain common, especially with regard to labor, the most densely populated part of the production process. Producer-driven production systems are responsible for the process of product production and circulation of enterprise management headquarters performed by control mechanisms, with some, or even many of these processes being carried out by other independent companies. Guided by “producers” commodity chains of commodity production, their product area is dominated by the economic strength of the core producer. However, within “buyer-driven” commodity chains within the industry, large retailers and trading companies, in many exporting countries—usually a third-world country—play a central role within the distribution of production networks.

This industry is dominated by trade, and relatively labor-intensive consumer products are common within the industry, such as clothing, footwear, household goods, and consumer electronics, in addition to a wide range of products like furniture and decorative articles made by hand ^[12]. The main characteristic is the integration of these companies, which usually do not have any production equipment. They are of “no production”, also known as “fables”, and such companies rely on complex outsourcing networks ^[13]. Indeed, they rely upon outsourcing vendors to perform almost all of their respective specialized workloads, such as providing design, engineering, manufacturing, packaging, shipping, and receiving services from all over the world. The core of the company’s main role is to manage its relationship network and ensure that each enterprise link can be perfectly combined. Producer-oriented companies tend to copy these functions throughout the different markets of the world within the “home” country of their entire business process, while the purchaser-oriented companies tend to subcontract the work to other the countries all over the world, only keep some functions—primarily the function of brand marketing and sales—in the home country, and set up different functions in different countries. With the comparison made above, the fashion industry could easily be categorized as a “buyer-driven” commodity chain.

3. Methodology

3.1. Case study

In the social and life sciences, a case study is a research method that involves an up-close, in-depth, and detailed examination of a subject relevant to the subject as well as its related contextual conditions. The “case” being studied may be an individual, organization, event, or action, existing in a specific time and place.

Although no single definition of the case study exists, case-study research has long had a prominent position in many disciplines and professions, ranging from psychology, anthropology, sociology, and political science to education, clinical science, social work, and administrative science ^[14–15]. However, Thomas offered a definition of the case study as: “Case studies are analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods. The case that is the subject of the inquiry will be an instance of a class of phenomena that provides an analytical frame — an object — within which the study is conducted and which the case illuminates and explicates.” ^[16].

According to J. Creswell, data collection in a case study occurs over a “sustained period of time” ^[17]. Case